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OPERATING COSTS AND CHARACTERISTICS OF MINIBUSES

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FINAL REPORT

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16. Abstract

This report presents an analysis of minibus operating characteristics based on operating data obtained from transit operators. The intent of this analysis is to identify the costs of operating minibuses and the manner in which those costs vary. It also seeks to clarify the conditions in which minibuses are the most cost-effective buses to operate. Representative cost and operating statistics are shown for prototypical applications of minibuses in environments found to be appropriate. The report does not emphasize minibus vehicle types which have consistently proved disappointing in transit service, but focuses instead on heavier duty models that are now favored by most minibus operators.

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PREFACE

This report was prepared for the Office of Socio-Economic and Special Projects of the Urban Mass Transportation Administration. It was prepared under the direction of and with the cooperation of Ron Nawrocki and John Durham of that office and Michael Wolfe and Arthur Priver of the Transportation Systems Center.

However, the contents of the report reflect the views of SG Associates, Inc. and Technology Research and Analysis Corporation. They are fully responsible for the facts, the accuracy of the data, and the conclusions expressed herein.

Our thanks are extended to the transit operators which provided operations data on minibuses. Their assistance and cooperation is greatly appreciated.

The staff oc SG Associates, Inc. responsible for preparation of this report are Stephen Andrle and Frank Spielberg. Arnie Hungerbuhler of Technology Research and Analysis Corporation is the primary contributor from that firm.

METRIC CONVERSION FACTORS

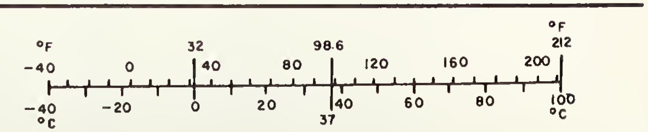
Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yerds	0.8	square meters	m^2
mi^2	squere miles	2.6	squere kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teespoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fehrenheit temperature	5/9 (after subtracting 32)	Celsius tempereture	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.

Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	squere centimeters	0.16	squere inches	in^2
m^2	square meters	1.2	squere yerds	yd^2
km^2	squere kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gel
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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I. INTRODUCTION AND SUMMARY

There has been considerable interest in minibuses over the last ten years as the public transit industry has introduced innovative services and emphasized special services to elderly and handicapped persons.

Large urban areas with new regional rail systems have introduced feeder services to stations, a use for which smaller coaches can be appropriate. Neighborhood-oriented transit services have been introduced and there is renewed interest in the timed-transfer concept. Minibuses may be appropriate for any of these services.

Smaller communities and rural areas have also been starting transit services where transit has never been or has been missing since the early 1950's. Typically, these operations are low volume services for which a coach smaller than the standard 40-foot coach is desirable.

Another type of service that has become more common recently is the downtown shuttle. Some large cities have introduced crosstown shuttles in the central business district to tie together parts of the downtown that are beyond comfortable walking distance.

These service innovations have spawned a whole generation of small buses. The majority of the new small buses have been produced by motor home manufacturers looking for a new market for their vehicles. School bus manufacturers have also produced small buses for transporting special education students and for the urban transit small bus market. Recently, new purpose-built buses have appeared on the market -- buses that were built exclusively for urban transit use.

With the variety of new vehicles and service types came controversy on the merits of small buses. The opinion of most transit operators who have experimented with small buses is that motor home conversions simply do not last in transit service. Opinion varies on other types of vehicles, but follows the theme of the heavier duty, the better.

This report presents an analysis of minibus operating characteristics based on operating data obtained from transit operators. The intent of this analysis is to identify the costs of operating minibuses and the manner in which those costs vary. It also seeks to clarify the conditions in which minibuses are the most cost-effective buses to operate. Representative cost and operating statistics are shown for prototypical applications of minibuses in environments found to be appropriate. The report does not emphasize minibus vehicle types which have consistently proved disappointing in transit service, but focuses instead on heavier duty models that are now favored by most minibus operators.

Operating data to support the analysis of minibus characteristics were requested from transit operators which operate minibuses. 11 transit operators known to operate minibuses were contacted, and useful data were obtained from seven. Neither operators known to have minibuses that are now unavailable in the U.S. nor operators only using minibuses in dial-a-ride service were contacted, because the focus of this evaluation is on fixed-route transit applications of minibuses. The data set assembled for this analysis is based on 194 individual vehicles and ten minibus vehicle models. Appendix B includes the data collected from the various transit properties, which, to protect confidentiality, are identified by letter in this report.

An effort was made to collect reliable data on minibuses across different duty cycles. Specifically, data from these operating environments obtained were:

- Feeder service to regional transit station and for activity center
- Downtowner shuttle in large city
- Small city transit

Data also collected for two generic categories of minibus vehicles were:

- Medium duty -- Modified automotive products with seating ranging from 18 to 32 passengers. The distinguishing feature of medium-duty minibuses is body-on-truck-chassis construction. School buses of various sizes are considered medium-duty.
- Purpose-built -- Small buses built especially for transit. Seating ranges from 18 to 32 passengers.

Light-duty minibuses are not considered by the study. A light-duty minibus is defined as an essentially unmodified automotive product seating from 9 to 18 passengers.

The intention was to develop operating cost models that reflected the duty cycle and the generic category (medium-duty or purpose-built) of minibus. While data were obtained from properties operating minibuses in different environments, the data do not support quantitative differentiation between duty cycles. The quantitative analysis is limited to distinguishing the performance characteristics of medium-duty from purpose-built vehicles.

As would be expected, data collected from different properties exhibit substantial variation due to different wage rates, benefits packages, maintenance practices, and allocation of administrative costs to transit. In order to adjust for these variations, operating cost

models are built on the most reliable data items such as driver labor hours, maintenance labor hours, gallons of fuel used, etc. A standard wage rate, benefits rate and fuel cost is then applied to data from all properties. Rates comparable to those paid by large city transit operators are used in the analysis. A nomograph is also included (Appendix A) to permit adjusting the magnitude of operating cost values to particular conditions.

Parts expenditures are used in the analysis directly as reported by the operators. No satisfactory index is available to adjust for variations in transit parts and materials costs by geographic sector. The Producer Price Index for Automobile Parts maintained by the U.S. Department of Commerce would have sufficed for this purpose, but it is not calculated by region of the country. Therefore, lacking an appropriate adjustment tool, parts costs are utilized directly.

Due to the variation in accounting practices, particularly with respect to administrative expenditures, it is not possible to develop a totally representative cost assessment for every property. In developing a generic operating cost model for medium-duty and purpose-built minibuses, coefficients for the descriptive variables are determined by assessing the range observed on each variable across the transit properties operating a particular category of minibus and selecting a representative coefficient.

Finally, to exhibit the effect of factors such as average speed, annual vehicle miles per vehicle, and frequency of stops on operating costs, the cost models for medium-duty and purpose-built minibuses are applied to prototypical operating environments to estimate actual costs. Costs are then summarized in a set of familiar measures such as cost

per revenue mile, passengers per revenue vehicle mile, etc. The resultant variation is substantial for different service types. The prototypical cases examined are:

- Feeder to regional transit
- Downtowner shuttle
- High capacity loop shuttle

A summary of the most significant findings follows.

SUMMARY

The primary differences between medium-duty and purpose-built minibuses are: (1) purchase price, (2) maintenance cost, and (3) life cycle. Purpose-built minibuses are roughly three times more expensive than medium-duty vehicles -- approximately $100,000 vs. $30,000. On the other hand, medium-duty vehicles are 25% to 45% more expensive to maintain than purpose-built. Purpose-built coaches also last three to four times longer than medium-duty coaches -- 12 years vs. three-four years.

To differentiate between the operating cost differences, the differences in purchase price and life cycle differences, a cost analysis over a comparable period of time is required. Analysis results with respect to operating cost, capital cost, and life cycle are summarized below.

Operating Cost[1/]

The fuel consumption element of operating cost varies between different minibus models, but does not vary consistently with respect to generic minibus category. Fuel economy is a function of many factors, such as vehicle weight, engine type, percentage of operating hours during which air conditioning is run, duty cycle, and proportion of time spent idling. The

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1. In this report, operating cost includes transportation (driver), maintenance, fuel, and administrative costs.

data assembled for this study are not sufficiently detailed to specify the nature of the relationship between these variables and fuel efficiency.

What is clear with respect to fuel economy, however, is that minibus fuel efficiency is constrained to a fairly narrow range, regardless of vehicle type. Since the data set does not permit developing specific relationships between fuel consumption and the various factors affecting it, a constant fuel efficiency of 2.1 kilometers per liter (4.8 mpg) was assumed for all minibus models.

Driver-related and overhead-related costs of transit operation do not vary with the type of vehicle operated, so these costs are treated as constants. These costs are a function of wage scale, vehicle hours operated, and size of the transit property, not vehicle type.

Operating costs models for medium-duty minibuses and purpose-built minibuses were developed from data reported by transit properties. For medium-duty buses, this cost equation was developed:

Annual Operating Cost = \$0.42 (Revenue Vehicle Kilometers)
+ \$19.0 (Revenue Vehicle Hours)
+ \$6500 (Fleet Size)

For purpose-built coaches, this cost equation is used:

Annual Operating Cost = \$0.34 (Revenue Vehicle Kilometers)
+ \$19.0 (Revenue Vehicle Hours)
+ \$6500 (Fleet Size)

The three-part model reflects the cost of fuel and maintenance as distance-related costs. Drivers wages and benefits are hour-related, and a fixed cost per coach is used as an estimate of administrative costs related to the size of the transit operation.

For comparison to minibuses, an operating cost model for standard coaches was also developed:

Annual Operating Cost = \$0.40 (Revenue Vehicle Kilometers)
+ \$19.0 (Revenue Vehicle Hours)
+ \$6500 (Fleet Size)

The derivation of these equations is discussed in Chapter III.

These cost equations indicate that without considering passenger capacity a purpose-built minibus is the most economical transit coach to operate. However, the critical parameter is not operating cost alone, but operating cost, plus passenger capacity and capital cost.

Total Annualized Cost

Most transit operators agree that medium-duty minibuses are 167,000 kilometer (100,000 mile) vehicles. This is a three year life, since the transit industry averages 50,000 to 58,000 kilometers per year (30,000-35,000 miles) on each coach. Both purpose-built and standard coaches are considered to be 12 year, 667,000 kilometer (400,000 mile) vehicles. Assuming these economic life spans for each vehicle type and 55,000 kilometers (33,000 miles) per year for each coach, the equivalent annual costs of purchasing and operating each transit coach are shown below:

Medium-Duty Minibus	\$87,000
Purpose-Built Minibus	\$85,800
Standard Coach	\$95,800

On an annualized cost basis at 10% discount rate, the equivalent annual cost of the three basic vehicle types is close. Allowing for variation among properties in maintenance and operating policies, there is no significant difference in equivalent annual cost between medium-duty and purpose-built minibuses. Standard coaches are about 10% more expensive than medium-duty coaches on an equivalent annual capital cost basis and 12% more expensive than purpose-built coaches.

Total Annualized Cost Per Capacity-Kilometer

The final element to be considered is the total annualized cost expressed on a capacity-kilometer basis. This measure places the total cost in the context of the passenger-carrying capability of each vehicle type.

The most direct way to express this relationship is to compare capacity-kilometers of service over one year to the annual costs of owning and operating each vehicle type. Table I-1 illustrates the respective costs per capacity-kilometer for medium-duty minibus, purpose-built minibus and standard coach, assuming each vehicle would be operated 55,000 kilometers (33,000 miles) in one year. The cost models shown earlier are used to estimate operating and maintenance costs. An average speed of 20 kilometers per hour (12 mph) is assumed.

It is about twice as costly on a capacity-kilometer of service basis to operate a medium-duty minibus than a standard bus; 50% more costly to operate a purpose-built minibus than a standard bus. The additional passenger-carrying capability of a larger vehicle makes the larger, and more expensive, vehicle the most economical by this criterion.

TABLE I-1

EQUIVALENT ANNUAL COSTS PER CAPACITY KILOMETER

	Seats	Passenger Places	Annual Place Kilometers	Annual Place Miles 2/	Annualized Capital Cost 1/	Annual Operating Cost 2/	Total Annualized Cost Per Place Kilometer	Total Annualized Cost Per Place Mile
Medium-Duty Minibus	20	35	1.925 million	1.155 million	$12,000	$75,000	$0.045	$0.075
Purpose-Built Minibus	30	50	2.751 million	1.650 million	$14,700	$71,100	$0.031	$0.052
Standard Bus	53	80	4.400 million	2.640 million	$22,000	$73,800	$0.022	$0.036

1. These purchase prices are assumed: Medium-Duty Minibus -- $30,000; Purpose-Built Minibus -- $100,000; Standard Bus -- $150,000. A 10% discount rate is used to annualize capital cost.

2. Assumes 55,000 km per year for each vehicle type and average speed of 20 km/hr (12 mph.).

Reliability

Reliability is another consideration in evaluating the relative performance of different vehicle types. Reliability refers to the time a vehicle can perform without breakdown. The minibus operators contacted by this study did not have vehicle reliability data in a form that could be readily used. Some indirect data were available, however, indicating that purpose-built minibuses travel as much as four times the miles between failures as medium-duty minibuses. The opinion of minibus operators tends to generally corroborate this finding. Operators who have recently replaced minibus vehicles or have recently started minibus service are selecting purpose-built coaches.

While the findings of this study regarding minibus reliability are not conclusive, the consensus opinion of the operators contacted is that purpose-built minibuses are more reliable than medium-duty minibuses.

Conclusions

The following conclusions are drawn from the analysis in this report:

(1) The primary advantage to a medium-duty vehicle is its low purchase price. For small, low volume transit properties without severe rush hour peaking, low initial cost may be the most significant factor. Medium-duty buses would be appropriate in this case.

(2) For most transit properties with rush hour peak loads, capacity is the most critical factor. Because of driver wage costs, two vehicles are more expensive than one no matter which is selected, so the largest vehicle is favored. Many large properties are adding articulated buses to their fleets for this very reason. A standard bus or larger is the most appropriate for this service type.

(3) In special circumstances where vehicle capacity is not the controlling factor, small buses can be the most economical option. Situations where the capacity of minibuses would not be a critical limiting factor include:

- Short routes -- Routes less than 8.3 kilometers (five miles) in length would not suffer overcrowding on minibuses at normal peak period residential boarding rates of 3 to 4 passengers per kilometer per bus. Feeder routes to transit stations are an example of this route type.

- Circulator Routes -- Circulator routes in downtown areas or activity centers are likely to have a more balanced pattern of on's and off's than other route types, thereby reducing the need for a large vehicle. Minibuses are regularly used in this environment today.

- Frequency-Constrained Routes -- Whenever the service environment is such that frequent service must be provided regardless of passenger demand, a small bus is likely to be the most economical. An airport shuttle is such a case. Most urban transit service is demand constrained, meaning sufficient buses are assigned to a route to carry the passengers. Whenever the frequency-constraint would dictate more service than the demand constraint, minibuses have a role.

The overall result of the analysis indicates that purpose-built minibuses have the lowest annualized cost of the three vehicle types studied. They have slightly lower operating costs than standard coaches, last as long as standard coaches and are less expensive to purchase. Because of their capacity limitation, however, operators can only capitalize on the cost advantage if the vehicles are deployed in the special circumstances described above. Any time, two minibuses would be required where one standard bus would suffice the cost advantage of a purpose-built minibus would be lost.

II. MINIBUS DURABILITY AND RELIABILITY

The perceived durability and reliability of minibuses vary considerably across vehicle types and manufacturers but accurate and statistically valid data on component reliability are difficult to obtain. This section describes indirect evidence from the data indicating that purpose-built minibuses are the most durable. General opinions from operators contacted during this study support this conclusion, and indicate that purpose-built minibuses are more reliable as well.

One measure of durability is simply the economic life of a vehicle. Medium-duty minibuses are considered three year, 167,000 kilometer vehicles. Purpose-built minibuses are considered 12 year, 667,000 kilometer vehicles, the same as standard coaches.

As a rule of thumb, annual maintenance costs should not exceed the equivalent annualized capital cost of a vehicle. If maintenance costs do exceed the annualized capital cost, the most cost-effective policy would be to sell and purchase new coaches. The year in which annualized capital costs are surpassed by maintenance costs defines the economic life of a vehicle. Since purpose-built minibuses last four times longer than lighter duty vehicles, they must be considered more durable by this measure.

The life cycle approach provides an indication that purpose-built coaches are the most durable. Reliability measures, however, relate to the incidence of failure in service. Several indications of comparative reliability were discovered and these are discussed here.

RELIABILITY MEASURES

Miles Between Road Calls

Distance traveled between road calls is the transit industry measure of vehicle reliability. Any time a vehicle fails for any reason that prevents continued service, a mechanic or tow truck must be dispatched. If passengers are on board, a relief bus must also be sent out. Obviously, a transit property tries to minimize the number of such failures, because passengers are inconvenienced and maintenance costs are increased.

To provide a benchmark value, a fleet of standard coaches will typically experience one road call for every 3300 to 5000 vehicle kilometers (2000-3000 vehicle miles). Since coaches average 50,000 kilometers per year, a rate of 4200 kilometers (2500 miles) between road calls is equivalent to one road call per month per coach.

Property D, operating 48 medium-duty minibuses, was experiencing one road call for every 890 vehicle kilometers (532 vehicle miles). When 32 TMC Citycruisers were added to the fleet, the fleet average kilometrage between road calls increased to 1560 kilometers (937 miles). The purpose-built TMC's were running about 3834 kilometers (2300 miles) between road calls, pulling up the fleet average substantially. Small properties with only 10-14 vehicles reported 5000 to 16,700 kilometers (3000 to 10,000 miles) between road calls on purpose-built Chance RT-50's.[1/]

The experience of these properties indicates that purpose-built coaches are at least four times more reliable than lighter duty coaches on a miles-between-road-call basis. The one to four ratio is based on the experience of the first property described above. The duty cycle,

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1. Road call data were obtained from properties B, C, and D as listed in Appendix B.

maintenance and operating procedures were the same for both vehicle types, so no variation in performance can be attributed to differences between properties. Higher values on the order of 15,000 to 16,700 kilometers (9,000 to 10,000 miles) between road calls were only noted for small properties and are probably too optimistic to be used for long range planning estimates.

Brake Life

Brake life is another category for which some data were available. The purpose-built TMC Citycruiser was reported to operate 33,340 to 41,700 kilometers (20,000 to 25,000 miles) between brake shoe replacement. This is also the typical range for standard coaches. A mixed-model fleet of medium-duty and purpose-built coaches was averaging 6700 kilometers (4000 miles) between relinings.[1/]

Short brake life is a typical complaint from properties using medium-duty vehicles for stop and start transit service. These vehicles have braking systems designed for vans or light trucks which do not typically undergo the stop-start cycle of transit vehicles. Heavy duty brakes can alleviate the problem, somewhat, but cannot compensate for insufficient design.

Other Components[2/]

The track record on other components was not readily available from minibus operators contacted during this study, either because vehicles were too new for data to be available or because it was not in useable

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1. Data from properties C and D respectively (Appendix B).

2. See: The Applicability of Non-Standard Buses for Service in the Washington Metropolitan Area, Washington Metropolitan Area Transit Authority, September 1978, pp. 69-80.

form. The nature of problems that are experienced by light and medium-duty minibuses that account for the lower reliability include the following:

- Gasoline Engines -- Low speeds and excessive idling can cause engine failure after less than 100,000 kilometers (60,000 miles). Diesels are better suited to low speed service.

- Transmissions -- Improper mating of engine and transmission can cause overheating and failure. This is a particular problem with modified automotive products.

- Suspension -- The spring and chassis suspension used in trucks and vans simply does not perform well in transit service. It provides a rough ride for passengers, and vibration causes body components to rattle loose. Purpose-built coaches now on the market use full air suspension as standard coaches do.

- Electrical System -- This is a particular problem with vehicles manufactured from a van or motor home base. Typically wiring is too light, alternators are too light and fuses are inadequate. Quite often operators report having to rewire vehicles and retrofit 120 AMP alternators. Wiring is not such a problem with vehicles built by school bus manufacturers.

- Body -- Poor body construction is a nagging and chronic problem. Water leaks, drafts, rattles, loose windows, broken window latches, broken door hinges, broken door stop arms, and a litany of similar problems are reported that can either put a vehicle out of service or make for an uncomfortable ride. Poor body construction coupled with inadequate suspension lead to short vehicle life. Both light and medium-duty vehicles suffer from this problem.

- Driver Compartment -- A problem with front engine vehicles where the engine is covered by a hood next to the driver in the interior of the vehicle is excessive engine heat. Drivers become very uncomfortable and will sideline such a vehicle intentionally if there is an alternative in the fleet. Adequate thermal insulation helps, but front-engine coaches are subject to this problem. The engine hood is also a problem for front door fare collection, because passengers enter well behind the driver.

In summary, engine and transmission problems are generally due to inadequate design. Transit service is very specialized. Van- and truck-based minibuses have been shown repeatedly to fail when subjected to the stress of continual low speed and frequent stops. Body and chassis problems in light and medium-duty minibuses are similarly the result of underestimating the punishment to which a transit vehicle is subjected in regular service.

III. MINIBUS OPERATING COSTS[1]

INTRODUCTION

Operating costs are a function of the vehicle that is operated, the duty cycle of operation and policies of a particular property. In determining the generic costs of minibus operation, the vehicle-related costs are of the greatest interest. Costs associated with duty cycle and operating property will differ from site to site for the same vehicle. In presenting operating costs for minibuses in this report, variations in cost due to vehicle characteristics are emphasized, while variations due to operating property are minimized by normalizing pay scales across the several properties from which data were obtained.[2] Differences in operating characteristics due to duty cycle are highlighted where data allow and are otherwise treated as prototypical cases in Chapter IV.

In this chapter, there is a discussion of each of the major cost components of minibus operation. The cost categories discussed are broken down into categories which primarily relate to the distance a vehicle is operated, to the hours of operation and to system overhead as shown below:

Distance-Related Costs

- Maintenance labor and benefits
- Maintenance materials
- Fuel

Hour-Related Costs

- Operator labor and benefits

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1. In this report operating cost includes transportation (driver), maintenance, fuel, and administrative costs.

2. Data are included in Appendix B.

Overhead-Related Costs

- General and administrative labor
- General and administrative materials, utilities, insurance, and other costs

This structure allows total costs to be related to vehicle and system operating parameters such as speed, fuel economy, and hours of service. These parameters are typically known or assumed in planning new services and are therefore inputs to estimating costs. Cost models are developed here based on data supplied by minibus operators. Default coefficients can be adjusted to particular circumstances by following a method shown in Appendix A.

DISTANCE-RELATED OPERATING COSTS

Clearly fuel costs are a function of the distance a vehicle travels. Maintenance costs are also considered distance-related, because the incidence of inspection, component wear and breakdown is related to the number of kilometers a vehicle travels.

Fuel

Data on fuel consumption was assembled from properties operating minibuses and is displayed according to the previously described categories of medium-duty and purpose-built. Table III-1 shows fuel economy in kilometers per liter and cost per kilometer.

To eliminate regional differences in fuel costs, both diesel fuel and gasoline are assumed to cost 32 cents per liter ($1.20 per gallon, Dec., 1980). The resulting fuel cost for purpose-built small buses runs between 12 and 22 cents per kilometer. Medium-duty buses exhibit roughly the same cost range from 13 to 19 cents per kilometer, with the typical value around 15 cents per kilometer.

TABLE III-1

FUEL COST COMPONENT

VEHICLE TYPE	Property/ Duty Cycle 1/	Number of Vehicles	Fuel Efficiency	Cost (1980$) Per Km	Per Mile
Medium-Duty					
Grumman 18 Passenger (Gas)	D/3	19	2.3 km/l (5.3 mpg.)	13.6¢	(22.6¢)
Carpenter 23 Passenger (Gas)	D/3	10	1.6 km/l (3.7 mpg.)	19.4¢	(32.4¢)
Carpenter 27 Passenger (Diesel)	D/3	19	2.4 km/l (5.6 mpg.)	12.8¢	(21.4¢)
Carpenter 35 Passenger (Diesel)	D/3	19	2.1 km/l (4.9 mpg.)	14.7¢	(24.5¢)
Superior 35 Passenger (Diesel)	D/3	7	2.3 km/l (5.3 mpg.)	13.6¢	(22.6¢)
Purpose-Built					
Chance RT-50 25 Passenger (Diesel)	B,C/2	28	2.5 km/l (5.8 mpg.)	12.4¢	(20.7¢)
TMC Citycruiser 31 Passenger (Diesel)	D/3	47	1.7 km/l (4.0 mpg.)	18.0¢	(30.0¢)
Mercedes 0309D 19 Passenger (Diesel)	A/1	16	2.4 km/l (5.5 mpg.)	13.1¢	(21.8¢)
Flxible HD-31 32 Passenger (Diesel)	E/4	15	1.4 km/l (3.2 mpg.)	22.5¢	(37.5¢)

1. Duty Cycle Code: 1. Airport Shuttle; 2. Small City, Fixed Route; 3. Rail Feeder, Fixed Route; 4. CBD Circulator, Fixed Route.

Notes: Diesel Fuel @ $1.20/Gallon
Gasoline @ $1.20/Gallon

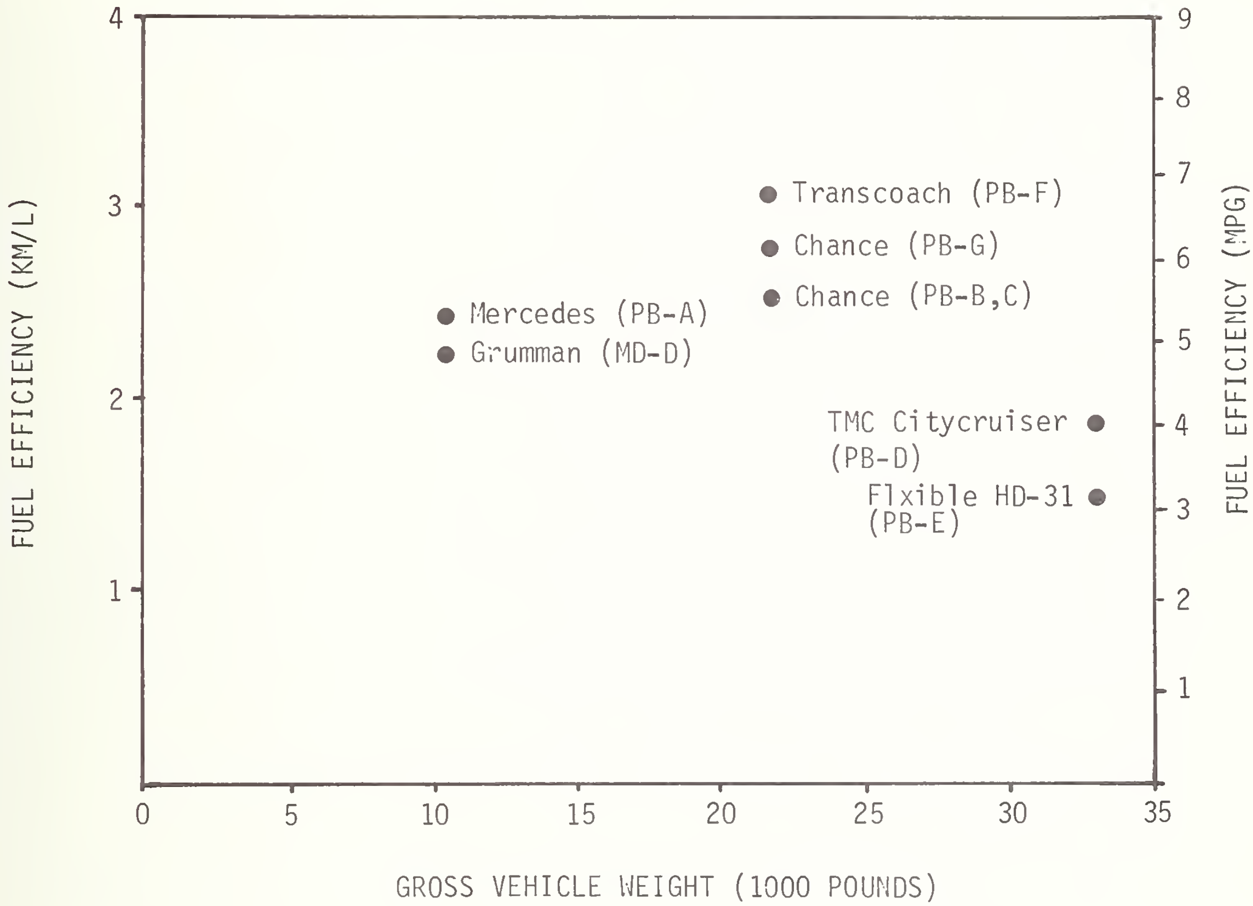
The fuel efficiency data do not show a consistent pattern with respect to generic vehicle category. Figure III-1 illustrates reported fuel economy for various vehicles plotted against gross vehicle weight as reported by manufacturers. For instance, in the 22,000 pound class, four data points representing 42 vehicles are shown. All are diesel engine, purpose-built small buses, but fuel efficiency varies 25% from 2.5 kilometers per liter to 3.1 kilometers per liter. The Chance vehicles run in small city, fixed route service and the Transcoaches run in CBD circulator service. Data for 32 TMC Citycruisers running as feeders to rail stations show 1.7 kilometers per liter. They are in the same fuel efficiency range as the Flxible HD-31 in the 33,000 pound class. The 10,500 pound Grummans, gasoline-powered, medium-duty minibuses exhibit about the same fuel efficiency as the heavier purpose-built Chance vehicles. The Grummans run a duty cycle comparable to the Chance vehicles.

No simple relationships can be drawn between gross vehicle weight, duty cycle and fuel efficiency. While one would hypothesize that definitive relationships do exist, the data collected for this report are not sufficiently detailed to explain the relationships. These data do seem to show that vehicles at the heavy end of the purpose-built weight range achieve slightly lower fuel efficiency than do other vehicles of both categories.

One can safely say that regardless of vehicle type and duty cycle, (1) minibus fuel efficiencies are constrained to a fairly narrow range, and (2) minibus fuel efficiencies are superior to those of standard coaches. The trade literature typically reports fuel economies for standard coaches in the 1.3 to 1.7 kilometers per liter range.

FIGURE III-1

FUEL EFFICIENCY RELATED
TO GROSS VEHICLE WEIGHT



Note: Letters in parentheses indicate purpose-built (PB) or medium-duty (MD) and the letter identifier of the transit property from which data were taken. See Appendix B.

There are also numerous factors which influence fuel efficiency in addition to vehicle weight, engine types, and duty cycle. Air conditioning, for one, can reduce fuel economy by 0.5 to 1.0 kilometers/liter when it is operating. Although the vehicles in this analysis are all equipped with air conditioning, there are no data on the air conditioning hours operated for each. This introduces variation into the data. Idling due to layovers is another source of variation in fuel efficiency data that is not accounted for. Duty cycle is a surrogate for traffic congestion and passenger loading effects on fuel economy, but is not a rigorous explanation of sources of variation.

In short, the data set assembled for this report was unable to find firm differences in fuel efficiency and fuel cost related to generic minibus category. Therefore, in developing operating cost models in this report, a figure of 15 cents per kilometer (25 cents per mile) is used for the fuel cost component for each minibus category. Specific vehicles in specific circumstances may do somewhat better or worse than this, but the data do not show a consistent pattern with respect to generic categories of minibus vehicle.

Maintenance

Maintenance costs are incurred in routine servicing, repair, supervision and stock room management. Mechanics, of course, are the backbone of the maintenance system. They typically represent about 60% of the maintenance staff. Positions are listed here from a transit property operating 150 coaches to provide an idea of personnel requirements.[1/]

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1. Madison, Wisconsin Metro. This is not one of the properties that contributed minibus operating data.

• Maintenance Supervisor	1
• Foreman	5
• A Mechanic	8
• B Mechanic	8
• C Mechanic	13
• Tire Man	1
• Service Man	9
• Utility Man	1
• Stock Man	2
• Maintenance Clerk	1
• Cleaner	2
• Paint and Body Man	1
	52

The number of coaches per mechanic is a useful measure to gauge the level of maintenance practiced on a particular property. The transit industry averages from 4 to 6 coaches per mechanic. This is in line with the personnel roster shown above. There are 29 mechanics for 150 coaches which is about one mechanic for every five coaches.

Five foremen supervise 29 mechanics, which is also a typical ratio in the industry. Using the coaches per mechanics ratio as the base for scaling a maintenance program and assuming that mechanics are about 60% of the maintenance labor force will yield an appropriate complement of maintenance personnel for a property of reasonable size.

For very small operations, these ratios may not hold, because some mechanics will do tire work, foremen may manage the stock room, etc. Typically, a small operation with 10 to 20 coaches can operate with fewer total maintenance personnel per coach than can larger operations.

The data obtained from minibus operators fall in line with typical industry practice as shown in Table III-2. The number of coaches per mechanic falls in the 4 to 6 range for all but an airport shuttle operation.

TABLE III-2

MAINTENANCE LABOR REQUIREMENTS

Property	Duty Cycle	Number of Minibuses	Coaches Per Mechanic	Monthly Man Hours/Coach
A	Airport Shuttle	16	8	26
B	Small City -- Fixed Route	12	6	39
C	Small City -- Fixed Route	10	4	35
D	Feeder to Suburban Rail Station	80	5	32
E	CBD Circulator	15	NA1/	NA1/
F	CBD Circulator	10	NA1/	NA1/
G	Suburb	10	NA1/	NA1/

1. Not available: Minibus fleet is a small segment of a large fleet.

The ratio of coaches to mechanics is shown for each property as is the number of labor hours per coach per month to illustrate that the level of maintenance is comparable across the properties and coach types represented. It should be noted in Table III-2 that the coaches per mechanic ratio and man-hours per coach ratio represent system averages for the properties from which the maintenance data were taken.

Monthly maintenance hours per coach was used as another measure of maintenance policy. This ratio fell in the range of 26 to 39 maintenance man-hours each month per coach for the properties evaluated. This does not include washers and cleaners but only mechanics' hours. A maintenance rule of thumb is that roughly a man-week is required per coach each month. This is another way of stating that one mechanic per four coaches is typically required.

Since most of the minibus fleets in the country are fairly new, some maintenance work is done under warranty. Warranty work tended to run $600 to $700 annually per coach where warranties were in effect. In later years, such work would be done in-house, so an estimate of 40 man-hours per month per coach is not an unreasonable estimate, even though it is the high end of the observed range.

Table III-3 shows the total maintenance costs per mile reported for properties operating various types of minibus coaches. Purpose-built buses incur maintenance costs at roughly 80% of the rate of medium-duty buses. Both parts and labor contribute to the cost differential. Parts typically run 40% to 45% of total maintenance.

It should be noted that maintenance costs have been normalized by assuming a standard rate of $16 per hour for labor and benefits. This is comparable to $12 per hour plus 30% benefits, which is a representative wage structure for mechanics in urban areas.

TABLE III-3

MAINTENANCE COST COMPONENT

VEHICLE TYPE	Property/ Duty Cycle	Number of Vehicles	Annual Maint. Hours	Normalized Maint. Labor @ $16/hour: Cost & Benefits	Maint. Parts and Material Cost	Annual Vehicle Kilometers	Maint. Labor and Benefits Cost Per:		Maint. Parts and Material Cost Per:		Total Maint. Cost Per:	
							Km	Mile	Km	Mile	Km	Mile
Medium-Duty												
Grumman 18 Passenger (Gas)1/	D/3	19	--	--	--	--	16.2¢*	27¢*	13.8¢*	23¢*	30.0¢	50¢
Carpenter 23 Passenger (Gas)1/	D/3	10	--	--	--	--	13.2¢*	22¢	9.0¢*	15¢*	22.2¢	37¢
Carpenter 27 Passenger (Diesel)	D/3	19	1310	$20,960	$ 17,800	167,000	12.6¢	21¢	10.8¢	18¢	23.4¢	39¢
Carpenter 35 Passenger (Diesel)	D/3	19	1702	$27,232	$ 21,800	167,000	16.2¢	27¢	13.2¢	22¢	29.4¢	49¢
Superior 35 Passenger (Diesel)1/	D/3	7	--	--	--	--	21.6¢*	36¢*	14.4¢*	24¢	36.0¢	60¢
Purpose-Built												
Chance RT-50 25 Passenger (Diesel)	C/2	12	4690	$ 75,040	$ 51,444	721,100	10.2¢	17¢	7.2¢	12¢	17.4¢	29¢
TMC Citycruiser 31 Passenger (Diesel)	D/3	47	13063	$209,008	$117,570	1,633,260	12.6¢	21¢	7.2¢	12¢	19.8¢	33¢
Mercedes 0309D 19 Passenger (Diesel)	A/1	16	4050	$ 64,800	$ 55,000	900,200	7.2¢	12¢	6.0¢	10¢	13.2¢	22¢
Flxible HD-31 31 Passenger (Diesel)2/	E/4	15	--	--	$ 2,017	27,780	--	--	7.8¢	13¢	--	--

Duty Cycle Code: 1. Airport Shuttle, 2. Small City, Fixed Route, 3. Rail Feeder, Fixed Route, 4. CBD Circulator, Fixed Route.

1. Only the total maintenance cost per vehicle mile is known for these vehicles on priority D. The split between parts and labor is estimated.
2. Data for one month only.

* Estimated

HOUR-RELATED COST

Bus drivers are paid by the hour not the mile, and therefore transportation costs are a function of vehicle hours, not vehicle miles.[1] It is satisfactory to express transportation costs on a per mile basis, however, as long as assumptions about average system speed do not change. Changes in average speed change the relationship between vehicle miles and operator pay hours. For instance, if transportation costs per vehicle mile developed for an urban system operating at an average speed of 20 kilometers per hour (12 mph.) are applied on a mile-for-mile basis to a shuttle system on separate guideway operating at an average speed of 33 kilometers per hour (20 mph.), operator costs will be overestimated by 66 percent. Since average system speed on a daily basis does not typically change radically between transit properties, calculating transportation costs on a per mile basis is generally safe. However, if a specific application is to have a substantially different average speed than a typical urban system, an adjustment is necessary. For this reason, transportation costs are distinguished from mile-related maintenance costs.

Transportation costs for minibuses are entirely a matter of wages paid by a particular property and the hours of operation. This component naturally varies from site to site. In order to compensate for this variation, a standard rate of $19 per hour for wages and benefits was assumed.

This rate is composed of average drivers wages, benefits and a pay hour factor. Average wages is self-explanatory. A value of $10 per hour is assumed in this analysis as representative of moderate-sized

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1. "Transportation Costs" as used in the transit industry includes drivers wages, drivers benefits, supervisors wages and benefits and other costs associated with putting buses on the street. Maintenance, fuel and administrative costs are not included.

transit properties. A benefits package of 30% is added to this and the wages plus benefits rate is multiplied by a 1.45 pay hour factor. The pay hour factor represents pull-on/pull-off time, spread time and other paid time off the vehicle. It converts revenue hours to paid driver hours. The product of \$10 x 1.3 x 1.45 is \$18.85. A value of \$19 is used for analysis.

The pay hour factor results from typical transit industry labor agreements and the heavily peaked nature of urban transit service. Pay hour factors for three representative transit systems are shown below:

Madison, Wisconsin Metro	1.43
Montgomery County, Maryland Ride-On	1.57
Washington, D.C. Metro	1.51

The value of 1.45 selected for this analysis could represent a medium-size transit property with a typical labor agreement.

In some minibus applications, transit labor agreements may not apply or may be specially negotiated. To accommodate such a situation, Appendix A describes a method to build up the vehicle hour coefficient in the model directly from an assumed wage rate.

Table III-4 shows transportation costs per mile for different properties in a variety of operating environments. Suburban and small city minibus operations are quite consistent at \$0.96 to \$1.04 per revenue kilometer. An airport shuttle using Mercedes small buses reports a higher cost per kilometer, because the average speed is much slower than experienced by the suburban small city operations. The slower speed means relatively fewer vehicle kilometers are traveled per unit of cost and relatively more hours are expended.

TABLE III-4

ANNUAL TRANSPORTATION COST COMPONENTS

VEHICLE TYPE	No. of Minibuses	Duty Cycle/ Property	Average System Speed		Normalized[1/] Wages and Benefits	Cost Per Rev.-Veh. Kilometer	Mile
Medium-Duty							
Mixed Fleet All Minibus	80	Rail Feeder Fixed Route/D	18 km/hr.	11 mph.	$3,182,500	$1.04	$1.73
Heavy-Duty							
Chance RT-50	10	Small City/C	19 km/hr.	12 mph.	$ 693,120	$0.96	$1.60
Chance RT-50	10	Small City/G	18 km/hr.	11 mph.	$ 545,300	$1.04	$1.73
Chance RT-50	12	Small City/B	19 km/hr.	12 mph.	$ 558,144	$0.96	$1.60
Flxible HD-31[2/]	15	CBD Circulator/E	6 km/hr.	4 mph.	$ 73,530	$2.85	$4.75
Transcoach	10	CBD Circulator/F	8 km/hr.	3 mph.	$ 555,900	$2.30	$3.84
Mercedes 0309-D	16	Airport/A	10 km/hr.	6 mph.	$1,710,000	$1.90	$3.16

1. To compensate for widely varying pay and benefit scales, a uniform rate of $19 per hour wages and benefits is assumed. Pay hours are assumed to be 45% greater than revenue hours, so a pay hour factor of 1.45 is included in the $19 per hour rate.

2. Data for one month only.

The same situation occurs in a downtown environment where average speeds can be as low as 5 or 6 kilometers (three to four miles) per hour. This results in a transportation cost per revenue vehicle kilometer in the $2.30 to $2.85 ($4.00 to $5.00 per mile) range. The radical difference in cost per kilometer, a function of vehicle speed, underscores the potential error if unit cost per kilometer is used indiscriminately as a cost estimating tool.

Note also in Table III-5 that downtowner vehicles tend to accumulate fewer annual kilometers per coach than do other vehicles. The airport shuttle plus the suburban and small city vehicles accumulate roughly from 50,000 to 65,000 kilometers (30,000 to 40,000 miles) per year. The Transcoaches in downtown service accumulated only 23,000 kilometers (14,400 miles) each, and the Flxible HD-31's would only accumulate 20,000 kilometers (12,400 miles) if 12 months of service comparable to the one month shown were operated. This is primarily a function of slower speed and relatively short service day.

The low annual kilometrage on downtown coaches indicates that they are underutilized. The industry average is between 48,000 and 56,000 kilometers (30,000 to 35,000 miles). This is a problem for coaches in a special service that are a small part of a much larger fleet. Operators claim that a specialized fleet within a larger fleet will always cost more to operate for the very reason that the fleet is unique. It is difficult to interline service, for instance, and to work the vehicles into maintenance rotation. Typically a higher percentage of spare vehicles is also needed. From an operating point of view, subfleets of specialized vehicles are not desirable unless there is a special circumstance that cannot be accommodated by standard coaches.

TABLE III-5

ANNUAL MINIBUS USE

VEHICLE TYPE	No. of Minibuses	Revenue Vehicle Kilometers	Revenue Vehicle Miles	Revenue Vehicle Hours	Annual Coach Usage Kilometers	Annual Coach Usage Miles
Medium-Duty						
Mixed Fleet All Minibus	121	2,948,300	1,842,700	167,500	36,850	23,030
Heavy-Duty						
Chance RT-50	10	692,150	432,592	36,480	69,220	43,260
Chance RT-50	10	504,580	315,364	28,700	50,460	31,540
Chance RT-50	12	560,000	350,000	29,376	46,670	29,170
Flxible HD-31 1/	15	24,750	15,465	3,870	19,800*	12,370*
Transcoach	10	231,600	144,760	29,260	23,160	14,480
Mercedes 0309-D	16	864,000	540,000	90,000	54,000	33,750

1. Data for one month only

* Estimated from one month of data.

ADMINISTRATIVE COSTS

Administrative costs are related to the size of a transit operation. A useful measure of size is the size of the vehicle fleet. Table III-6 shows the administrative costs for all-minibus systems for two properties where administrative costs were allocated to transit.

Reliable administrative data for all-minibus systems are not readily available for two reasons. First, minibuses constitute only part of a vehicle fleet for many properties, and administrative costs are not allocated to specific vehicle types. Second, minibus purchases are frequently made by small transit systems that do not fully allocate administrative costs to the transit system. Insurance, for instance, frequently falls under an umbrella policy for city-operated systems such that full cost is not necessarily allocated to transit. Also, top level management is frequently divided between transit and other duties.

As a practical matter, however, there is no reason to believe that fully allocated administrative costs for operating a minibus fleet are substantially different than fully allocated costs for operating a full-size bus fleet. The figures shown in Table III-6 are close to fully allocated costs, but some percentage of administrative costs may not be included. The annual administrative cost per vehicle in the fleets shown tends to be between \$5,000 and \$6,000. For comparison, data from another study show the annual administrative cost per vehicle of a 140 bus transit property (full-size buses) to be around \$7300 per vehicle.[1/] On a per kilometer basis, this places administrative costs in the 13 cents to

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1. SG Associates, Inc., Technical Memorandum No. 1, Dane County Phase I Alternatives Analysis, Bus Operating Costs and Impacts, February 1980 (Unpublished).

TABLE III-6

ANNUAL ADMINISTRATIVE COSTS

System	No. of Vehicles	Administrative Costs: Labor and Benefits	Administrative Costs: Non-Labor	Admin. Cost Per Vehicle
D	80	124,800	266,875	4895
B	12	37,582	30,962	5712

16 cents per vehicle kilometer range (20 to 25 cents per mile) for a property operating its vehicles, the typical industry average of 50,000 kilometers per year.

Given the above discussion, a figure of $6500 per fleet vehicle will be used in this study to reflect administrative costs of minibus operation.

TOTAL MINIBUS OPERATING COST

The only area in which operating costs for different categories of minibuses are found to vary significantly is in maintenance. Purpose-built coaches experience a maintenance cost of about 19 cents per kilometer (32 cents per mile), versus 22 cents to 36 cents per kilometer (37 to 60 cents per mile) for medium-duty coaches. Fuel costs and fuel efficiency vary, roughly from 12 cents per kilometer (20 cents per mile) to 18 cents per kilometer (30 cents per mile), but there is no consistent pattern. Transportation and administration costs are not functions of vehicle type, so these cost components do not vary with minibus type.

Given these findings, operating cost models for two categories of minibus are developed -- medium-duty and purpose-built. Representative values for each of the cost components discussed in this chapter are incorporated in model coefficients. A three-part model structure is used reflecting distance-related costs, hour-related costs, and costs associated with the size of the vehicle fleet. Two terms are shown in the coefficient to distance-related costs. The first is the fuel cost component and the second is the maintenance component. The cost models for medium-duty and purpose-built minibuses are shown below:

- Medium-Duty

  Total Annual Operating Cost = (\$0.15 + 0.27) (Revenue Veh. Kilometers)
  + \$19.00 (Revenue Vehicle Hours)
  + \$6500 (Fleet Coaches)

- Purpose-Built

  Total Annual Operating Cost = (\$0.15 + 0.19) (Revenue Veh. Kilometers)
  + \$19.00 (Revenue Vehicle Hours)
  + \$6500 (Fleet coaches)

Table III-7 summarizes these equations in English units and also shows an operating cost model for standard coaches which is developed in the next section.

Each of these expressions can be reduced to a simple cost per vehicle-kilometer figure by making assumptions regarding average vehicle speed and annual kilometers per bus. The data show 20 kilometers per hour to be a typical speed and 50,000 kilometers per year typical annual kilometrage per coach. Applying these values to each of the equations shown above yields the following operating cost on a per kilometer basis:

- Medium-Duty: \$1.50/vehicle kilometer or \$2.50/vehicle mile
- Purpose-Built: \$1.42/vehicle kilometer or \$2.37/vehicle mile

The annual operating cost for a medium-duty minibus operating 50,000 kilometers would be \$75,000, and \$71,100 for a purpose-built minibus. A purpose-built minibus is roughly 5% less costly to operate than a medium-duty minibus.

TABLE III-7

SUMMARY OF OPERATING COST MODELS
(English Units)

Medium-Duty Minibus:

Total Annual Operating Cost = (\$0.25 + 0.45) (Revenue Vehicle Miles)

+ \$19.00 (Revenue Vehicle Hours)

+ \$6500 (Fleet Coaches)

Purpose-Built Minibuses:

Total Annual Operating Cost = (\$0.25 + 0.32) (Revenue Vehicle Miles)

+ \$19.00 (Revenue Vehicle Hours)

+ \$6500 (Fleet Coaches)

Standard Coach:

Total Annual Operating Cost = (\$0.34 + 0.32) (Revenue Vehicle Miles)

+ \$19.00 (Revenue Vehicle Hours)

+ \$6500 (Fleet Coaches)

Note: First term of the revenue vehicle mile coefficient represents fuel costs and the second term represents maintenance labor and benefits.

TOTAL ANNUAL COSTS

Purpose-built minibuses are less costly to operate than medium-duty minibuses, because of lower maintenance costs, but are more costly to purchase. Estimated 1980 purchase prices for air-conditioned, lift equipped vehicles are as follows:

- Medium-Duty $ 30,000
- Purpose-Built $100,000

Medium-duty vehicles have a three year 167,000 kilometer economic life and purpose-built vehicles have a 12 year 667,000 kilometer economic life -- the same as a full-size transit vehicle.

The annual costs of owning and operating a vehicle are the sum of the annual operating cost plus the annualized capital cost over the expected life of the vehicle.[1/] Annual costs for each vehicle type are shown in Table III-8.

Given that specific bid purchases for a vehicle vary depending on size of purchase, timing and market conditions, and that operating practices vary somewhat between properties, Table III-8 indicates that there is no appreciable cost difference between different classes of minibuses. There are differences in ride quality, image, etc., but not in cost.

It should be noted, however, that Federal transit assistance programs provide a greater share of capital purchases than of operating costs, so from the local perspective, the purpose-built vehicle is a better buy. From a global perspective, however, differences are minimal.

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1. Annualized capital cost is calculated using the capital recovery method at a 10% discount rate. This reflects an opportunity cost of money 10% greater than inflation.

TABLE III-8

TOTAL CAPITAL AND OPERATING COSTS
OF MINIBUSES AND STANDARD COACHES

	Annualized Capital	Annual Operating	Total Annual Cost
Medium-Duty	$12,000[1]	$75,000	$87,000
Purpose-Built	$14,700[2]	$71,100	$85,800
Standard Coach	$22,000[3]	$73,800	$95,800

1. $30,000 purchase price: 3 year life cycle: 10% discount rate
2. $100,000 purchase price: 12 year life cycle: 10% discount rate
3. $150,000 purchase price: 12 year life cycle: 10% discount rate

Note: A less expensive minibus in the $20,000 range with a 3 year expected life would have a total annual cost of $83,040 if an annual operating cost of $75,000 is assumed. This is in the same range as the medium-duty and purpose-built vehicles.

FULL-SIZE COACH COSTS

For comparison to minibuses, it is useful to consider operating costs, capital costs and life cycle costs for standard coaches. For operating cost, the following model is appropriate:

$$\text{Total Operating Cost} = (\$0.20 + 0.19)\,(\text{Revenue Vehicle Kilometers}) + \$19.00\,(\text{Revenue Vehicle Hours}) + \$6500\,(\text{Fleet Size})$$

The hour-related and fleet-related costs are the same as used for minibuses. The distance-related cost assumes the same maintenance cost as a purpose-built minibus, but reflects higher fuel use. At 1.5 kilometers per liter (3.5 mpg.) which is typical for full-size transit buses and $0.32 per liter ($1.20 per gallon) for diesel fuel, the cost per kilometer of fuel would be 34 cents. Using 32 cents per mile for maintenance plus 34 cents per mile for fuel yields 66 cents per mile for distance-related operating cost. Annual costs for a standard vehicle operating 50,000 kilometers at 20 kilometers per hour (12 mph.) would be $73,800.

A representative 1980 capital cost for a standard coach is $150,000. Over a 12 year economic life at 10% discount rate, this is equivalent to $22,000 per year. The total annual cost of a standard coach over its life cycle is $95,800 per year. This is about 10% greater than a medium-duty minibus and 12% greater than a purpose-built minibus.

COST AND CAPACITY CONSIDERATIONS

The total annual capital and operating costs of medium-duty minibuses, purpose-built minibuses and standard buses is not dramatically different as shown in the previous section. There is a substantial difference in cost per passenger place, however. This is particularly true when comparing

minibuses of either variety to standard buses.

The annual costs of owning and operating the various vehicle types can best be compared to capacity by calculating the cost per capacity unit as measured in passenger places. Medium-duty minibuses are assumed to have 35 passenger places, purpose-built minibuses have 50 passenger places and standard coaches have 80 passenger places. Table III-9 summarizes vehicle capacities and Table III-10 illustrates the respective costs per passenger place.

Although both types of minibuses exhibit lower annualized costs than standard coaches, the standard coach is far superior on the cost per passenger-place measure. In a typical transit operating environment with peaked rush hour loadings, high vehicle capacity is an asset. Rush hour loads can be served with fewer vehicles. The cost per passenger-place measure reflects this asset and explains why minibuses are not commonly found on routes that have a high peaking factor. Table III-10 shows that a medium-duty minibus is more than twice as costly as a standard coach on a passenger-place basis. A purpose-built minibus is 43% more costly than a standard coach. These cost characteristics limit the economical use of minibuses to special situations which will be discussed in the next chapter.

SENSITIVITY TO COST ESCALATION

Operating Cost

The majority of minibus operating costs are composed of labor costs, so operating costs are quite sensitive to wage inflation. Fuel is still a relatively small percentage of total operating cost, but is becoming more important as fuel costs increase. Parts, similarly, are a relatively small percentage of operating costs. Table III-11 shows operating cost

TABLE III-9

BUS CAPACITY

	Seated[1/]	Standing[2/]	Passenger Places[3/]
Medium-Duty	20	15	35
Purpose-Built	30	20	50
Standard Coach	53	27	80

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1. This may vary depending on presence of wheelchair stanchions.

2. This is crush load standing capacity, not service policy.

3. Conforms to 4 square feet per passenger for typical models of each type, calculated on gross dimensions.

TABLE III-10

COST PER PASSENGER PLACE OF MINIBUSES
AND STANDARD COACHES

	Annualized Capital Cost	Annualized Capital Cost Per Passenger Place	Annual Operating Cost	Annual Operating Cost Per Passenger Place	Total Annualized Cost	Total Annualized Cost Per Passenger Place
Medium-Duty Minibus	$12,000	$343	$75,000	$2143	$87,000	$2486
Purpose-Built Minibus	$14,700	$294	$71,000	$1420	$85,700	$1714
Standard Coach	$22,000	$275	$73,800	$ 923	$95,800	$1198

Note: Passenger places are assumed as follows:

Medium-Duty Minibus -- 35 passenger places
Purpose-Built Minibus -- 50 passenger places
Standard Coach -- 80 passenger places

TABLE III-11

COMPARATIVE OPERATING COSTS EXPRESSED ON A DISTANCE BASIS[1]

	Purpose-Built			Medium-Duty		
	Cost Per			Cost Per		
	Revenue Km	Revenue Mile	Percent	Revenue Km	Revenue Mile	Percent
Operating Labor	$0.95	$1.58	66.6%	$0.95	$1.58	63.2%
Maintenance Labor	0.10	0.17	7.2	0.14	0.24	9.6
Administrative Labor[2]	0.05	0.08	3.4	0.05	0.08	3.2
Parts and Materials	0.09	0.15	6.3	0.13	0.21	8.4
Fuel	0.15	0.25	10.5	0.15	0.25	10.0
Administrative Costs[2]	0.08	0.14	6.0	0.08	0.14	5.6
	$1.42	$2.37	100.0%	$1.50	$2.50	100.0%

1. Costs calculated using models developed in this report. Assume 50,000 kilometers per year per coach at 20 km/hr. (12 mph.).

2. Administrative costs such as utilities, liability losses, purchased services and interest are shown as 65% of fixed overhead costs. This ratio can change from year to year depending on claims, insurance premiums, etc.

components on a revenue vehicle kilometer basis for purpose-built and medium-duty minibuses. Costs are calculated according to the cost model for a vehicle running 50,000 annual kilometers at an average speed of 20 kilometers per hour (12 mph.).

Table III-11 indicates that 76% to 77% of minibus operating costs are composed of operating, maintenance and administrative labor plus fringe benefits. Parts and Materials run between 6% and 8%; fuel is about 10% and administrative nonlabor costs are about 6% of total operating costs. This breakdown makes it clear that wages have more to do with transit operating costs than any other single component.

Since most labor agreements are tied to the level of cost escalation in the economy, roughly 75% of transit operating costs will mirror that trend directly. Table III-12 shows the Consumer Price Index for recent years which can be used to estimate the likely increase in wages.

The Producer Price Index for Automotive Parts is a national index of cost increases to producers for materials. Parts and Materials for maintenance would tend to follow this index. Table III-12 shows a 27.4% increase for auto parts between December 1979 and December 1980. The Office Supply Index is also shown for comparison, but is applicable to only a minor segment of transit costs.

Percentage increases for fuel are meaningless in the present environment, due to OPEC influence on crude petroleum prices. Since 1973, diesel fuel has increased roughly 700% from about 15 cents per gallon to $1.20 per gallon. This is comparable to a 35% increase each year over seven years. In reality, sharp increases have occurred due to the OPEC oil embargo in 1974, the Iranian Revolution, and other international events.

TABLE III-12

INDICES OF COST ESCALATION BY SECTOR

	1980	1979	1978	1977
CONSUMER PRICE[1/] INDEX	258.4	229.9	202.9	186.1
% Change	+12.4%	+13.3%	+9.0%	---
PRODUCER PRICE[2/] INDEX FOR AUTO-MOTIVE PARTS	300.6	235.9	215.7	201.7
% Change	+27.4%	+8.2%	+6.9%	---
OFFICE SUPPLY[3/] INDEX	202.2	190.6	164.4	151.6
% Change	+6.1%	+15.9%	+8.4%	---

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1. 1967 = 100.
2. 1967 = 100.
3. 1967 = 100.

Source: U.S. Department of Commerce. Index volumes are for December of each year.

The decontrol of domestic oil plus the unpredictability of international events adds further uncertainty to fuel cost estimates. It appears that fuel costs will continue to increase as a percentage of transit budgets.

If inflation continues at its current pace, transit labor costs can be expected to increase at least 12% per year and other cost increases will likely exceed 13% given recent trends. Weighting the expected increase in rates by the percentage share of a transit budget contributed by each sector will provide a rough estimate of costs for the coming year. An example is shown below:

Wages	77% x 1.12	0.862
Fuel	10% x 1.35	0.135
Parts	7% x 1.13	0.079
Other	6% x 1.13	0.068
		1.144

At present cost escalation rates, total transit operating costs will increase about 14% per year. This is, of course, subject to variation depending on the results of labor negotiations in contract years on specific properties, on fuel rate increases, and on the overall rate of inflation.

The differences between purpose-built minibuses and medium-duty minibuses with respect to operating and maintenance cost escalation is minimal. Fuel is the most volatile cost item and both categories of minibuses are comparable in fuel efficiency. Minibuses will, however, look more favorable with respect to standard buses as fuel cost increases. Purpose-built minibuses are 5% to 6% less expensive to operate than standard buses at present, and could improve their relative position by 1 or 2 percentage points per year if fuel costs continue to average annual increases of 35 percent.

Capital Cost

Purchase prices for transit vehicles have escalated rapidly in recent years and will likely continue to do so. Representative costs as of December 1976 for transit vehicles with air conditioning and lifts are shown below compared to 1980 estimated prices.[1/]

	1976	1980	% Change
• Minibus, Inc. (Now Chance RT-50)	$56,500	$110,000	+95%
• Superior Pacemaker	$18,756	$ 30,000	+60%
• GMC 40-ft Coach	$75,000	$150,000	+100%

In four years, the cost of transit vehicles has essentially doubled. Some vehicles have not increased a full 100%, but the rate of increase is still rapid. Estimating a future price in this environment is difficult. It might be expected that the cost of transit vehicles could continue to increase at least as fast as the general inflation rate, and probably somewhat faster, given past observations. Due to the recent entry of foreign bus manufacturers in the U.S. market, however, competition should increase, tending to hold price increases down. An estimate of 14% to 15% annual increase in bus prices over the next few years would be a reasonable estimate.

The rapid escalation in equipment costs is another factor against using small buses. Not only is it advantageous to keep vehicle miles to a minimum, but it is advantageous to keep fleet requirements as low as possible. Using the largest capacity vehicle consistent with the service environment accomplishes both of these objectives.

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1. For 1976 Prices: Bus Specification and Price Summary, Iowa Department of Transportation, December 1976. 1980 prices are as reported by manufacturers.

IV. PROTOTYPICAL MINIBUS APPLICATIONS

Three prototypical minibus applications are described in this section to illustrate operating characteristics and annual costs of minibus services. The first prototypical case is comparable to bus service provided to suburban rapid rail or commuter rail stations. This is a fairly low volume situation in which minibuses circulate through neighborhoods, providing access to regional transit facilities. The second case typifies a downtowner shuttle service operating at higher volumes and slower speed. The final case is a high capacity minibus system that illustrates the maximum passenger volume situation in which minibuses should be considered.

In addition to describing the prototypical characteristics of minibuses in different environments, the question of using a standard bus instead of a minibus is also examined.

The parameters that are considered in illustrating prototypical applications are:

- Peak Passenger Capacity Required
- Vehicle Capacity
- Service Interval
- Route Length
- Stop Spacing
- Travel Speed

The passenger capacity requirements of a particular application determine the amount of service that must be provided. This service capacity is a function of vehicle size and frequency. The number of coaches required,

in turn, is a function of frequency, average travel speed and route length. Average travel speed is related to the acceleration/deceleration characteristics of the vehicle, maximum speed, and stop spacing. Each of these parameters must be specified for each prototypical application.

To preface the prototypical system descriptions, a discussion of key parameters follows. The maximum values of the various parameters are illustrated as well as the range of values associated with minibus services.

LIMITING CHARACTERISTICS OF MINIBUS SERVICE

Service Frequency and Vehicle Capacity

Vehicle capacity and service frequency determine the upper capacity limit of a minibus system. The range of capacity for minibuses is from 20 to 50 passengers as shown earlier in Table III-9. This is calculated from gross vehicle dimensions, allowing 4 square feet per passenger. The upper end of the range compares to the crush capacity of a TMC Citycruiser -- 50 passengers: 30 seated and 20 standing.

The minimum service interval at which a minibus system can be operated with curb space for only one vehicle per stop is 2 minutes. A minibus can accelerate and decelerate at 2.5 mph./sec. It takes from 1.5 to 2.5 seconds to load a passenger under the best conditions.[1/] If a maximum cruise speed of 33 kilometers per hour (20 mph.) is assumed for a minibus, the sum of acceleration time, deceleration time and passenger

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1. Bus Routes and Schedule Planning Guidelines, NCHRP #69, May 1980, p. 69. If deboarding passengers must be considered as for a coach with only one door, an additional 1.7 seconds per deboarding passenger must be allowed. Interim Materials on Highway Capacity, Transportation Research Circular #212, January 1980, p. 87.

loading time is 40 seconds for a stop with 12 passengers. The stop time varies with the number of passengers boarding at the peak load stop.

Table IV-1 shows the bus bay requirements for various bus frequencies and passenger volumes, assuming random coach arrivals according to the summed Poisson distribution. A bus volume in excess of 30 vehicles per hour (2 minute service interval) runs the risk of delay at stops with more than 12 passengers. Since the peak load stop establishes the constraint for the entire system, 30 vehicles per hour is the maximum frequency at which a minibus system should be operated without providing a second bus stop position at high volume load points. With stopping space for two buses at each stop and adequate roadspace for coaches to bypass each other, 60 vehicles per hour can safely be operated in most circumstances. Higher frequencies require additional curb spaces.

Route Length and Load Profile

Route length and load profile are related to vehicle frequency and capacity in determining whether or not minibuses are appropriate. Transit properties typically favor standard size coaches, because they offer greater capacity to accommodate the cumulative boarding pattern of most urban transit routes. In fact, articulated buses are finding favor in some cities because of their increased passenger capacity.

Minibuses are most effective on shorter routes or shuttle routes where passenger volume is not as likely to exceed vehicle capacity. Figure IV-1 illustrates the domain of route length and passenger demand where medium-duty, purpose-built and standard buses are appropriate. The figure illustrates the combination of passenger boarding rates and route lengths at which the various vehicle types would reach capacity.

TABLE IV-1

BUS BAY REQUIREMENTS[1/]

BUS BAYS REQUIRED

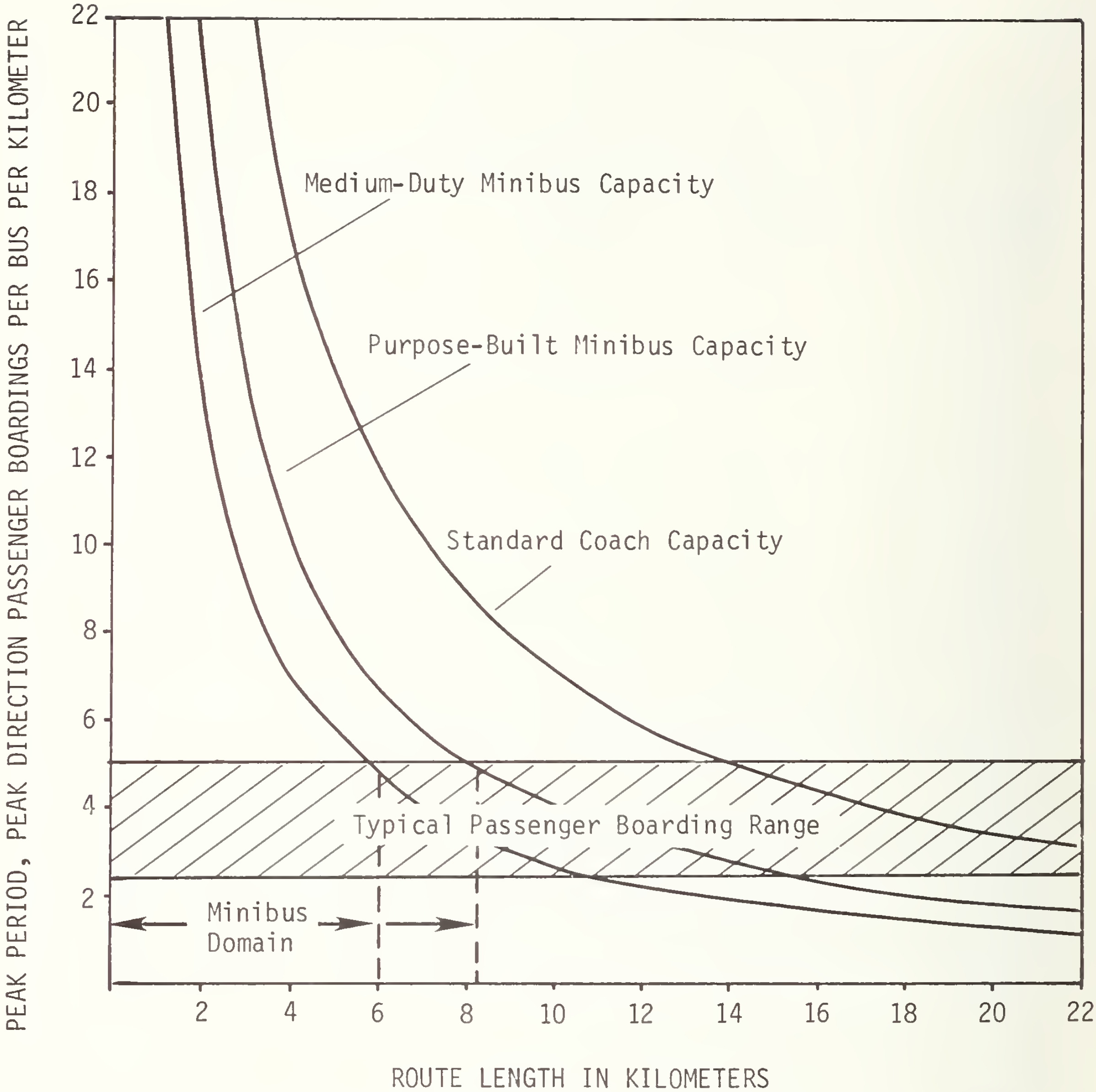
Peak Buses Per Hour	Service Time At Stop (Passenger Boardings)[2/] 20 Sec. (2 Pass.)	30 Sec. (7 Pass.)	40 Sec. (12 Pass.)	60 Sec. (22 Pass.)
15	1	1	1	1
30	1	1	1	2
45	1	2	2	2
60	1	2	2	3
75	2	2	3	3
90	2	2	3	4
105	2	3	3	4
120	2	3	3	5

1. Source: Bus Route and Schedule Planning Guidelines, NCHRP #69, May 1980, p. 40.

2. Service time includes both the actual stopping time, plus the acceleration and deceleration phase. Times are based on a maximum cruise speed of 32 kph. (20 mph.); 4.0 kph./sec. (2.5 mph./sec.) acceleration and deceleration; 2 seconds per passenger for boarding. For single door operation, allow 1.7 seconds per alighting passenger in addition to 2 seconds per boarding passenger.

FIGURE IV-1

RANGE OF ROUTE LENGTHS APPROPRIATE
FOR SELECTED VEHICLE TYPES
(Cumulative Load Profile)



Note: The curves represent the combination of boarding rate and route length at which each vehicle type would reach capacity if loading were cumulative, e.g., AM peak period inbound route. Capacity policy is defined as 1.33 x seats. Medium-Duty capacity -- 28 passengers; Purpose-Built -- 41 passengers; Standard Coach -- 71 passengers.

Capacity is defined not as total passenger places, but as 1.33 x seats. A standee policy of 33% is a reasonable representation of actual practice.

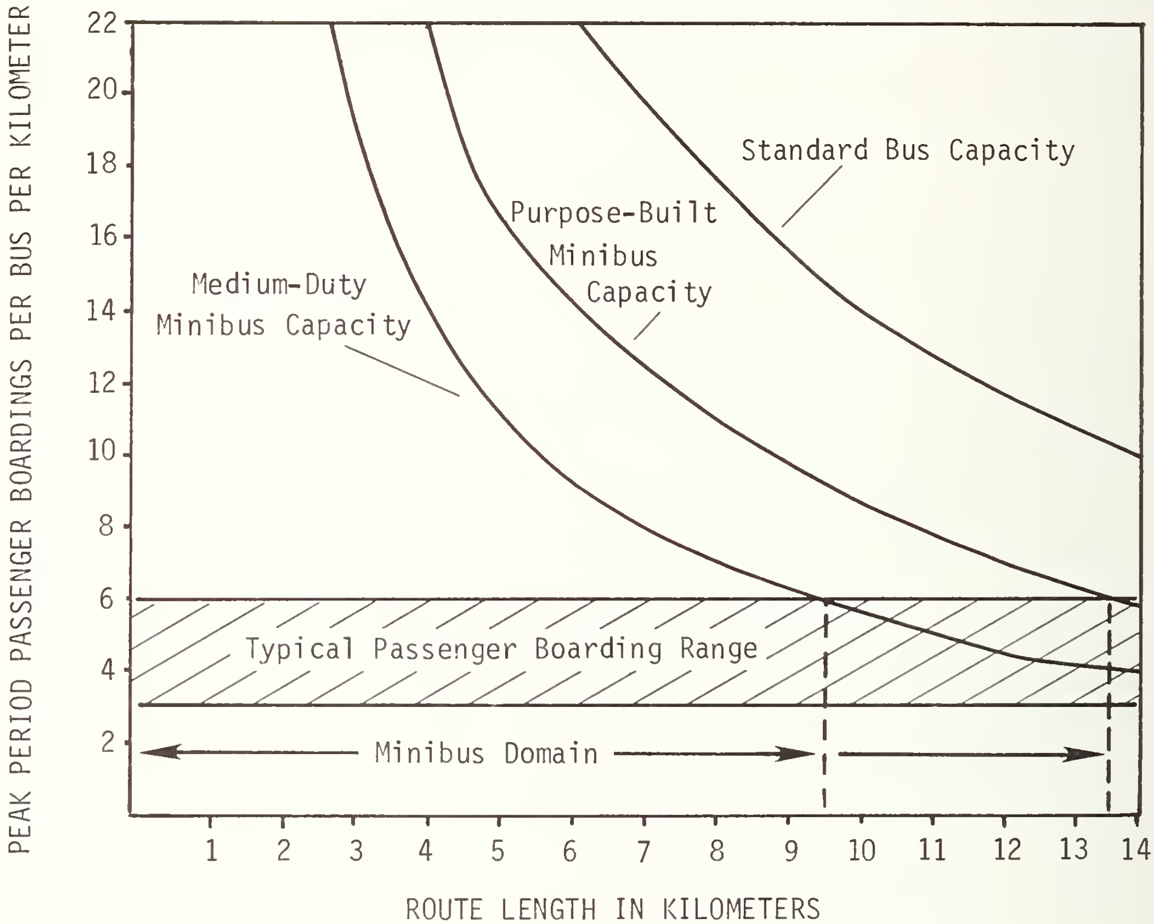
The shaded area shows the typical range of peak period passenger boardings per kilometer for urban transit routes at typical frequencies. For example, at an average boarding rate of 5 passengers per kilometer and a route length of 15 kilometers, 75 passengers would board the vehicle - a capacity load for a standard coach. A transit operator would strive to schedule a service interval on a peak hour route such that each bus would accumulate a full load, resulting in an average maximum boarding rate of about 5 passengers per kilometer for a 15 kilometer route. The point at which each vehicle capacity curve crosses into the typical passenger boarding rate range roughly defines the maximum route length for that type of vehicle. The figure indicates that 6 kilometers (3.6 miles) is about the limit for a 21 seat vehicle; 8.3 kilometers (5 miles) is the approximate limit for a 31 seat vehicle; a 53 seat vehicle can perform comfortably on route lengths up to 15 kilometers (9 miles).

The example in Figure IV-1 indicates that minibuses are confined to short, probably feeder-type routes, when the route load profile is cumulative. However, when the load profile is balanced (on's roughly equal off's along the route), a minibus is almost always appropriate. Figure IV-2 shows the minibus domain for such a balanced route. A 21 seat vehicle would serve well on routes up to 9.5 kilometers (5.7 miles) and a 31 seat vehicle would suffice on routes up to 13.5 kilometers (8 miles). A route that exhibits balanced loading and unloading is typically a shuttle-type route and they seldom exceed 13-14 kilometers, so minibuses are appropriate

FIGURE IV-2

RANGE OF ROUTE LENGTHS APPROPRIATE
FOR SELECTED VEHICLE TYPES

BALANCED LOAD PROFILE
TRIP LENGTH IS ONE
HALF ROUTE LENGTH



Note: The curves represent the combination of boarding rate and route length at which each vehicle type would reach capacity if passenger trip length were one-half of the route length and on's and off's were balanced. Capacity is defined as 1.33 x seats. Medium-Duty capacity -- 28; Purpose-Built capacity -- 41; Standard Coach capacity -- 71.

for this type of service. Unless demand is very high, a standard coach would typically offer excess capacity.

It should be noted that in practice, it would be customary to determine the peak load point volume of a route and select a combination of vehicle capacity and service interval that would satisfy demand at the peak load point. In this analysis, an average passenger boarding rate was used as a surrogate for peak load point demand, assuming that a vehicle frequency was offered appropriate to the overall level of demand. The conclusions regarding route lengths appropriate for the various vehicle types hold for passenger volumes typically encountered. If passenger volumes are unusually high in a particular situation, the guidelines would not necessarily hold, because one would always favor a large capacity bus over a minibus. For a shuttle route, hourly volumes in excess of 400 people at the peak load point would warrant standard size coaches.

Average Speed

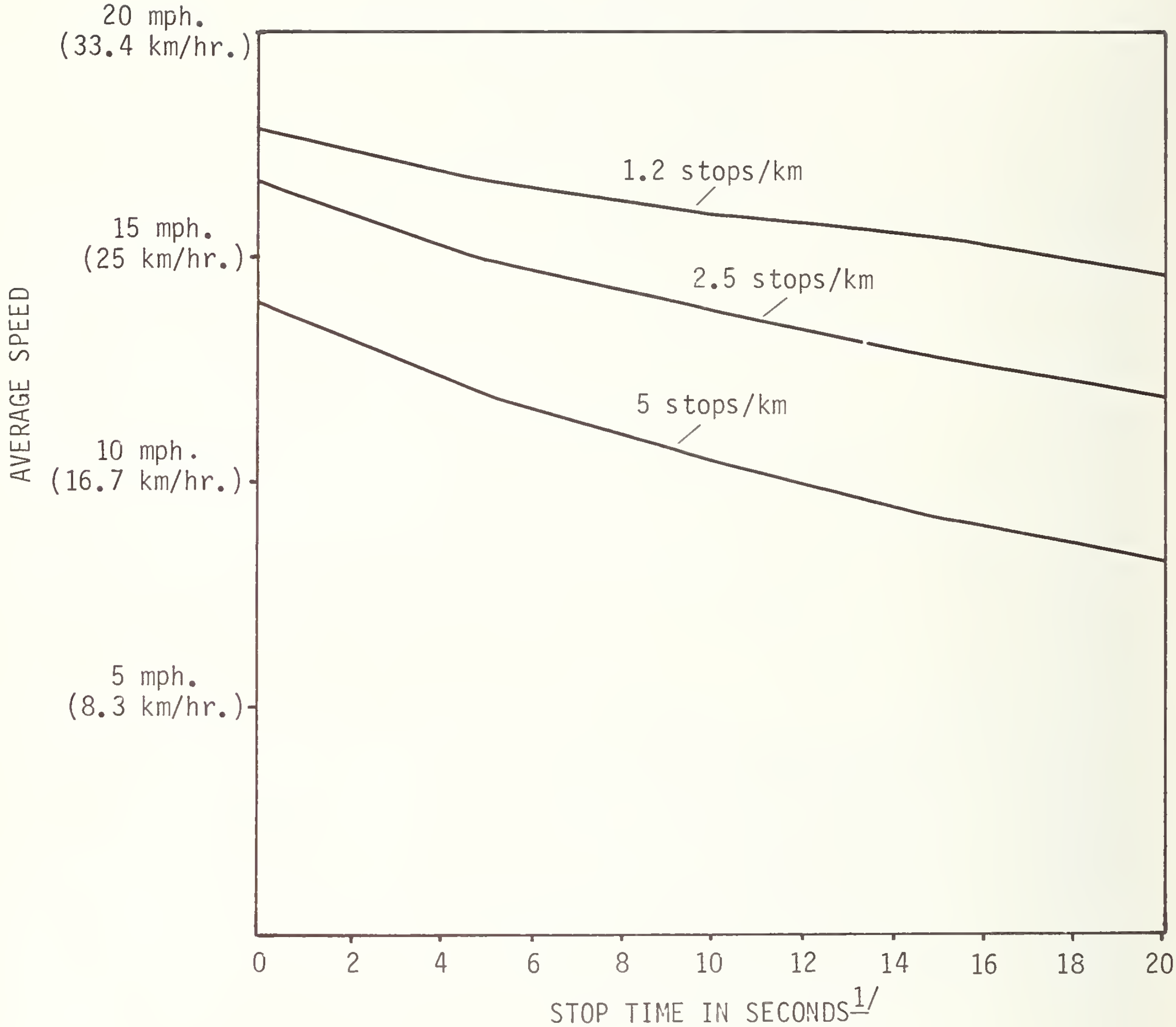
Average system speed is a function of vehicle acceleration characteristics, maximum cruise speed, number of stops per kilometer, and duration of stops. Duration of stops is, in turn, related to the passenger volume boarding the vehicle. Figure IV-3 illustrates the impact of passenger loading and station spacing on average speed when cruise speed is 33 kilometers per hour (20 mph.).

Average speeds can range from 5 to 36 kilometers per hour, depending on the combination of factors assumed. Typical systemwide average speeds for urban bus systems are from 18 to 23 kilometers per hour. Slower speeds in the 5 to 13 kilometers per hour are common in downtown route sections with slower traffic conditions and stops every block or two. Speeds from

FIGURE IV-3

AVERAGE MINIBUS SPEED

RELATED TO STOP TIME AND STOP SPACING



1. To estimate passenger volume, assume 2.0 seconds per boarding passenger. For single door operation, add an additional 1.7 seconds per alighting passenger. If boarding and alighting passengers are balanced, this will reduce average speed by about 2.5 to 3.0 kilometers per hour from what is shown on the curve.

23 to 30 kilometers per hour are observed on suburban route sections. Limited-stop suburban service can average 33 to 36 kilometers per hour. Average speeds higher than this can only be achieved in express service on freeways or arterials with few traffic or signal delays.

Estimating Equations

Two estimating equations are utilized in this section to calculate coach requirements and bus kilometers based on assumptions regarding route length, average speed and frequency of service. The estimating equations are as follows:

- Coaches Required

$$\frac{\text{Round-Trip Route Kilometers}}{\text{Km/Hr.}} \times \text{Buses/Hour} = \text{Buses Required}$$

- Bus Kilometers Per Route

$$\text{Hours of Service} \times \text{Km/Hr.} \times \text{Buses Required} = \text{Bus Kilometers}$$

These equations must be applied to periods of uniform service frequency.

These equations are used in the following sections to calculate annual bus kilometers for prototypical systems. Annual bus hours are derived by dividing bus kilometers by average system speed. Coach requirements are calculated as shown above. These values are inputs to the cost models developed in the previous section. From them, estimated annual operating costs for the prototypical minibus applications are derived.

FEEDER MINIBUS SYSTEM

A feeder to rapid rail or commuter rail stations is a practical application of minibus technology. It is appropriate for minibuses, because routes are short. The capacity of a standard bus is not necessary when passengers accumulate for only a short distance. At passenger boarding rates of 3 to 5 passengers per vehicle per kilometer and bus frequencies greater than two per hour, feeder routes up to 8.3 kilometers (5 miles) in length are appropriate for minibuses.

Table IV-2 illustrates the characteristics of a prototypical feeder service to one suburban rail station. The service described features three routes, 7.5 kilometers (4.5 miles) long operating on a 15-minute peak period headway with an average speed of 23.3 kilometers per hour (14 mph.).

There are several items that should be noted in Table IV-3 that distinguish the characteristics of this service from other prototypical cases that follow:

- This is a typical service with respect to headway, and passenger volume. Passengers per vehicle kilometer of 1.26 (2.10 per vehicle mile) is representative of average transit service productivity.

- Maximum travel speed reflects residential circulation, and the average speed is in the typical range for suburban service.

- The peak-to-base ratio, daily hours of service, and equivalent annual days of service are also in the standard industry range.

- The fleet size is large enough to maintain annual distance traveled per coach in the range of 50,000 to 58,000 kilometers per year (30,000 to 35,000 miles per year). Distances in excess of this violate accepted maintenance practices.

TABLE IV-2

PROTOTYPICAL FEEDER ROUTES
DESCRIPTIVE STATISTICS

Route Characteristics	
Number of Routes	3
Length of Routes	7.5 kilometers (4.5 miles) one-way
Number of Stops/Kilometer	8
Maximum Speed	33 km/hr. (20 mph.)
Average Speed	23 km/hr. (14 mph.)
Headway	15 Min. Peak/30 Min. Base
Vehicles Required	8 Peak/4 Base
Minibus Fleet Size	11
Service Characteristics -- Peak Hour	
Peak Hour Passengers	500
Average Trip Length	5 kilometers (3 miles)
Peak Hour Bus Kilometers	186 (112 bus miles)
Peak Hour Seat Kilometers	5600 (3360 seat miles)
Peak Hour Place Kilometers	9335 (5600 place miles)
Average Passengers Per Stop, Each Bus	0.9
Peak Hour Passenger Kilometers	2200 (1320 passenger miles)
Passengers/Vehicle Kilometer	2.68 (4.46 passengers/vehicle mile)
Passenger Kilometers/Place Kilometer	.24
Passenger Kilometers/Seat Kilometer	0.45
Service Characteristics -- Daily and Annual	
Peak/Base Ratio	2.0
Daily Hours of Service	18
Daily Bus Kilometers	2053 (1232 bus miles)
Daily Bus Hours	88
Annual Bus Kilometers	605,850 (363,440 bus miles)
Annual Bus Hours	25960
Annual Bus Kilometers/Bus	55,077 (33,040 bus miles)
Annual Bus Hours/Bus	2360
Daily Passengers	2940
Annual Passengers	764,700
Annual Passengers/Vehicle Kilometer	1.26 (2.10 per vehicle mile)

Notes: Service Annualization Factor 295; Passenger Annualization Factor 260. Purpose-built bus is assumed with 30 seats and 50 passenger places.

- The Peak Hour load factor as measured in passenger kilometers per seat kilometer is 0.45. Again, this reflects the largely unidirectional flow of peak period transit passengers in a commuting environment. There is substantial unused seat capacity and even more unused place capacity resulting from the peaked nature of commuting travel.

This case depicts minibuses operating in a service environment that is quite similar to existing suburban conditions with a strong passenger environment. Minibuses are appropriate because of the short route length. The same rate of passenger demand as shown in this case would overload a minibus if routes were substantially longer.

Table IV-3 illustrates the annual operating costs for this prototypical case using both purpose-built and medium-duty minibuses. The purpose-built buses are 6% less expensive to operate than the lighter duty vehicles. Both varieties of minibuses could provide adequate capacity for the feeder service, but the superior maintenance performance of purpose-built vehicles makes them less costly to operate. On a total annualized cost basis, however, there is less than 2% difference between the two vehicle types.

DOWNTOWN MINIBUS SHUTTLE

A downtown shuttle is a fairly common application of minibuses. Frequencies are high and routes are short so that large vehicle capacity is not needed. On's and off's are more balanced in a downtown shuttle environment than in a CBD-oriented radial environment, so the lower capacity minibus is appropriate.

The downtown shuttle described here is 5 kilometers long (3 miles) with five stops per kilometer and maximum cruise speed of 25 kilometers per hour (15 mph.). It carries 3360 passengers per day, and 500

TABLE IV-3

PROTOTYPICAL FEEDER ROUTES
OPERATING COSTS

	Purpose-Built	Medium-Duty
Annual Operating Cost	$771,900	$819,148
Annual Operating Cost Per:		
Vehicle Kilometer	$1.27 ($2.12/mile)	$1.35 ($2.25/mile)
Vehicle Hour	$29.73	$31.55
Passenger	$1.01	$1.07
Coach	$70,170	$74,470
Annualized Capital Cost[1/] (11 vehicles)	$162,000	$132,000
Annual Operating Cost	$771,900	$819,148
Total Annualized Cost	$933,900	$951,148
Total Annualized Cost Per:		
Vehicle Kilometer	$1.54 ($2.57/mile)	$1.57 ($2.62/mile)
Vehicle Hour	$36.00	$36.66
Passenger	$1.22	$1.24
Coach	$84,900	$86,500

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1. See Table III-8

Note: The capacity ranges of purpose-built minibuses and medium-duty minibuses overlap. The service described by Table IV-2 could be run with either vehicle type, so costs are shown for both.

passengers in the peak hour. Table IV-4 describes the characteristics of the prototypical downtown shuttle.

Items to note in Table IV-4 are listed below:

- The service is 10 hours per day, so it is not designed to carry rush hour commuters. A service day from 8 a.m. to 6 p.m. would be representative.

- The passenger volume of 3360 per day is comparable to one-half the volume carried by the Los Angeles downtown minibus.

- Average speed and maximum speed are slower than in the suburban feeder case, reflecting more congested downtown conditions.

- The level of service is very good -- only 8 minutes between buses.

- Due to the fact that passenger average trip length is only one-half of the route length, only 50% of the seat kilometers are utilized. This is higher, however, than the load factor obtained in the suburban case.

- Productivity on a vehicle-kilometer basis is high, despite the low load factor. The annual passenger per vehicle kilometer of 7.5 (12.5 passengers per mile) is over four times greater than a typical system average productivity.

- With an average of 1.3 passengers per stop, 24 stops per bus trip, and passenger trip length one-half the route length, an average of 15 passengers would be on board at any given time.

- Because of the short service day, only 34,400 kilometers (21,250 miles) per year are accumulated on the coaches. This is one-third less than the industry average, indicating that the vehicles in this service should be rotated into other duty cycles to increase their annual kilometrage.

This downtown shuttle system is extremely productive by transit industry standards, where overall productivity is typically about 1.65 passengers per vehicle kilometer. It still shows excess seat capacity, however, because of the short passenger trip length. Theoretically, a bus could turn its load over twice in one trip, which is not typical when serving CBD-bound commuters with traditional bus service. This

TABLE IV-4

DOWNTOWN MINIBUS SHUTTLE
DESCRIPTIVE STATISTICS

Route Characteristics

Number of Routes	1
Length of Routes	5 kilometers (3 miles) One-Way
Number of Stops Per Kilometer	8
Maximum Speed	25 km/hr. (15 mph.)
Average Speed	13 km/hr. (8 mph.)
Headway	8 minutes
Vehicles Required	6
Minibus Fleet Size	7

Service Characteristics -- Peak Hour

Peak Hour Passengers	500
Average Trip Length	1.5 kilometers
Peak Hour Bus Kilometers	80 (48 bus miles)
Peak Hour Seat Kilometers	2400 (1440 seat miles)
Peak Hour Place Kilometers	4000 (2400 place miles)
Average Passengers Per Stop, Each Bus	1.3
Peak Hour Passenger Kilometers	450 (750 passenger miles)
Passengers Per Vehicle Kilometer	6 (10 per vehicle mile)
Passenger Kilometers/Place Kilometer	0.31
Passenger Kilometers/Seat Kilometer	0.52

Service Characteristics -- Daily and Annual

Peak/Base Ratio	1
Daily Hours of Service	10
Daily Bus Kilometers	800 (480 bus miles)
Daily Bus Hours	60
Annual Bus Kilometers	248,050 (148,800 bus miles)
Annual Bus Hours	18,600
Annual Bus Kilometers Per Bus	35,423 (21,250 bus miles)
Annual Bus Hours Per Bus	2657
Daily Passengers	3360
Annual Passengers	1,041,600
Annual Passengers Per Vehicle Kilometer	4.2 (7 per vehicle mile)

Note: Assumes directional balance in passenger demand. Annualization Factor is 310. Purpose-built coach is assumed with 30 seats and 50 passenger places.

short trip length accounts for both the high passenger per vehicle kilometer value and the relatively low load factor.

In a shuttle environment, small buses can be very productive and provide adequate capacity. Capacity is quite sensitive, however, to the average trip length of passengers and the directional balance. A shuttle, like any transit system, must be designed in practice to meet the capacity requirements of the highest volume section of the route. If the passenger load is not balanced as is assumed in this case, the favorable operating profile shown here could not be achieved.

Table IV-5 shows the operating cost of providing downtown shuttle service with two different classes of minibuses. Purpose-built vehicles are 5% less costly to operate in this environment than medium-duty vehicles. The cost saving with purpose-built minibuses is less in this environment than in the feeder environment, because speeds are slower and a greater percentage of operating costs are hour-related rather than distance-related. The operating cost per vehicle kilometer is approximately 60 cents per kilometer higher than in the feeder case. This is primarily due to the low annual kilometrage, to the slower average speed, and to the fixed overhead costs associated with operating a fleet of buses. The fixed costs are spread over fewer annual kilometers, so the cost per kilometer is substantially higher.

Total annualized costs for each vehicle type are identical in this case for all practical purposes. The lower capital cost of the medium-duty vehicle, even given its shorter economic life (three years vs. 12 years). is enough to offset the operating cost advantage of the purpose-built vehicle.

TABLE IV-5

TYPICAL DOWNTOWN MINIBUS
OPERATING COST

	Purpose-Built	Medium-Duty
Annual Operating Cost	$483,720	$503,060
Annual Operating Cost Per:		
Vehicle Kilometer	$1.95 ($3.25/mile)	$2.03 ($3.38/mile)
Vehicle Hour	$26.00	$27.05
Passenger	$0.26	$0.27
Coach	$69,100	$71,865
Annualized Capital Cost[1/] (7 vehicles)	$102,900	$ 84,000
Annual Operating Cost	$483,720	$503,060
Total Annualized Cost	$586,620	$587,060
Total Annualized Cost Per:		
Vehicle Kilometer	$2.36 ($3.93 veh.mile)	$2.37 ($3.95 veh. mile)
Vehicle Hour	$31.50	$31.50
Passenger	$0.56	$0.56
Coach	$83,800	$83,870

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1. See Table III-8

Note: The capacity ranges of purpose-built minibuses and medium-duty minibuses overlap. The service described by Table IV-4 could be run with either vehicle type, so costs are shown for both.

HIGH CAPACITY SHUTTLE APPLICATION

A high capacity minibus system is illustrated here to indicate the practical limits of minibus capacity. It is assumed that a maximum capacity environment would occur in an airport or major activity center, that the minibuses would operate on public streets, and that adequate curb space is available for bus stops.

The analysis is conducted for 1 peak hour to illustrate system capacity. Costs are then calculated on an annual basis, assuming a weekly service profile such that the equivalent of 310 weekday service days are operated per year.

Service characteristics in this high capacity environment are described for both a purpose-built minibus and a standard 53 passenger transit coach. Standard coach is shown in comparison to a minibus, because its additional vehicle capacity allows the passenger load to be carried with fewer vehicle kilometers, while maintaining an acceptable vehicle frequency.

In Table IV-6 these items are noteworthy:

- The shuttle system has relatively few stops -- 2 per mile -- because it is designed to serve discrete activity locations within a large activity complex.

- Average speed is higher than in the downtown environment because of fewer passenger stops.

- The service runs on a 2 minute service interval, 30 buses per hour.

- The total fleet required is more than twice the number of vehicles needed to meet the schedule. This results from the high annual vehicle kilometrage and the fact that the peak-to-base ratio is 1. Most transit systems have a peak-to-base ratio of at least 2. This results in lower daily kilometrage, because much of the fleet is used only for peak hour trippers. The large fleet size is necessary to maintain annual kilometers per coach in the range of 50,000 to 58,000. Kilometers per coach greater than this does not allow sufficient

TABLE IV-6

HIGH CAPACITY MINIBUS LOOP SHUTTLE
DESCRIPTIVE STATISTICS

Route Characteristics	Purpose-Built Minibus	Standard Coach
Number of Routes	1	1
Route Length (loop)	5 km (3 miles)	5 km (3 miles)
Number of Stops	6	6
Maximum Speed	25 km/hr. (15 mph.)	25 km/hr. (15 mph.)
Average Speed	18 km/hr. (11 mph.)	18 km/hr. (11 mph.)
Headway	2 minutes	3.25 minutes
Vehicles Required	9	5
Minibus Fleet Size	20 1/	11 1/
Service Characteristics -- Peak Hour		
Peak Hour Passengers	1600	1600
Average Trip Length	2.5 km (1.5 mile)	2.5 km (1.5 mile)
Peak Hour Bus Kilometers	165 (99 miles)	93 (56 miles)
Peak Hour Seat Kilometers	4950 (2970 seat miles)	4950 (2970 seat miles)
Peak Hour Place Kilometers	8251 (4950 place miles)	7468 (4480 seat miles)
Average Passengers Per Stop -- Each Bus	6	6
Peak Hour Passenger Kilometers	4000 (2400 passenger miles)	4000 (2400 passenger miles)
Passengers/Vehicle Kilometer	9.7 (16.2 per mile)	17.0 (28.5 per mile)
Passenger Kilometers/Place Kilometer	0.48	0.54
Passenger Kilometers/Seat Kilometer	0.80	0.80

1. Excessive spares required to keep annual distance travelled per coach within the acceptable range of 50,000 to 58,000 kilometers per year.

Note: Standard coach assumes 53 seats and 80 passenger places. Purpose-built minibuses assume 30 seats and 50 passenger places.

TABLE IV-6 (Continued)

HIGH CAPACITY MINIBUS LOOP SHUTTLE
DESCRIPTIVE STATISTICS

Service Characteristics -- Daily and Annual 2/	Purpose-Built Minibus	Standard Coach
Peak/Base Ratio	1	1
Daily Hours of Service	20	20
Daily Bus Kilometers	3300 (1980 bus miles)	1867 (1120 bus miles)
Daily Bus Hours	180	102
Annual Bus Kilometers	1,023,200 (613,800 bus miles)	578,780 (347,200 bus miles)
Annual Bus Hours	55,800	31,620
Annual Bus Kilometers/Bus	51,160 (30,690 miles)	52,600 (31,563 miles)
Annual Bus Hours/Bus	2790	2874
Daily Passengers	16,000	16,000
Annual Passengers	4.96 million	4.96 million
Annual Passengers/Vehicle Km	4.84 (8.08 per mile)	8.58 (14.3 per mile)

2. 10% of Daily Riders in Peak Hour. Annualization factor is 310.

Note: Standard coach assumes 53 seats and 80 passenger places. Purpose-built minibuses assume 30 seats and 50 passenger places.

vehicle maintenance time. If annual kilometers in the vicinity of 100,000 kilometers per coach (60,000 miles) were operated, maintenance staff and facilities would have to be doubled, and the life of the coaches in years would only be about 6 years instead of the 12 years normally expected.

- The load factor of 0.80 passenger kilometers per seat kilometer is very high. This can only be accomplished because the demand pattern hypothesized here is not markedly peaked and is balanced in both directions. The minibus and standard bus systems are scaled to operate at the same load factor, indicating comparable service quality.

- The passenger demand shown for the system is high. This is shown intentionally, because this is a high capacity environment. For reference, the daily passenger volume is about three times the daily volume carried by the shuttle system at Washington's National Airport.

The comparative costs of operating a purpose-built minibus, medium-duty minibus or standard bus are shown in Table IV-7. Medium-duty vehicles are 5% more costly to operate than purpose-built coaches, but standard buses are 40% less costly. Standard coaches, because of their larger capacity, could save $640,000 a year in operating costs.

This large saving occurs, because the standard coaches can provide the needed capacity by operating only 56% of the vehicle kilometers operated by the minibuses. Standard buses are 4% more costly on a per kilometer basis, but they run so many fewer vehicle kilometers that the cost saving is substantial.

When the effect of capital cost is considered, the cost relationship between vehicle types used does not change, but the dollar magnitudes are altered. On a total annualized cost basis, standard coaches would cost $690,600 per year less than purpose-built minibuses and $716,400 less than light duty minibuses. This cost differential is larger than the differential considered on operating cost alone. The reason for this

TABLE IV-7

HIGH CAPACITY MINIBUS
LOOP SHUTTLE
OPERATING COST

	Purpose-Built	Medium-Duty	Standard
Annual Operating Cost	$1,540,066	$1,619,860	$901.432
Annual Operating Cost Per:			
Vehicle Kilometer	$1.51 ($2.51/mile)	$1.58 ($2.64/mile)	$1.56 ($2.60/mile)
Vehicle Hour	$27.60	$29.00	$28,51
Passenger	$0.31	$0.33	$0.18
Coach	$77,000	$81,000	$81,950
Annualized Capital Cost[1/]	$ 294,000	$ 240,000	$ 242,000
Annual Operating Cost	1,540,066	1,619,860	901,432
Total Annualized Cost	$1,834,066	$1,859,860	$1,143,432
Total Annualized Cost Per:			
Vehicle Kilometer	$1.79 ($2.99/mile)	$1.82 ($3.03/mile)	$1.97 (3.29/mile)
Vehicle Hour	$32.88	$33.35	$36.16
Passenger	$0.37	$0.37	$0.23
Coach	$91,700	$93,000	$103,950

1. Twenty vehicles for purpose-built and medium-duty minibuses; 11 vehicles for standard coaches. See Table III-8, page 38.

Note: The capacity ranges of purpose-built minibuses and medium-duty minibuses overlap. The service described by Table IV-6 could be run with either type of minibus so costs are shown for both. Standard coach service is scaled to provide the same level of service as measured by passenger kilometers per seat kilometer, so the service is comparable.

effect is that fewer standard coaches are required to serve the passengers, and even though they cost more per vehicle, overall system costs are less.

The cost measures shown in Table IV-7 indicate that total cost must be considered as well as performance measures in evaluating performance. On a cost per vehicle kilometer, per vehicle hour and per coach basis, minibuses are superior to standard coaches in this situation. On a total system cost basis and cost per passenger basis, however, the standard coach is substantially better, because fewer of them are needed and fewer vehicle kilometers are operated. The effect of vehicle capacity on total operating cost is more dramatic than the relative performance characteristics of the vehicles.

MINIBUS VERSUS STANDARD BUS

The decision to use a minibus instead of a standard bus in a particular situation is often dictated by considerations other than operating cost. The need for the maneuverability of a shorter vehicle is frequently the reason cited, or reduced obtrusiveness in neighborhoods. If minimum policy headways are apt to guarantee far more capacity than will be utilized, as is the case in many smaller communities, minibuses are favored precisely because they offer less excess capacity. On short, shuttle-type routes, minibuses can be utilized, because such routes exhibit a more balanced pattern of boardings and disembarkings than longer routes and consequently do not require large vehicle capacity. Since such routes are often downtown-only routes, maneuverability is also a factor.

The issue of when a minibus is appropriate must be addressed, because there are conflicting forces at work. Purpose-built minibuses are cheaper to operate per mile than standard buses, but the high capacity case just

examined indicates that standard buses can be much more economical than minibuses based on total operating costs. This section discusses the circumstances that favor minibus application over standard buses.

The cost models developed for purpose-built minibuses and standard buses indicate that purpose-built minibuses are about 5 cents per kilometer (9 cents per mile) cheaper to operate than standard buses, primarily due to better fuel economy of the smaller vehicles. Medium-duty minibuses are about 8 cents per kilometer (13 cents per mile) more expensive than standard buses, primarily due to high maintenance costs. Refer back to Figure III-7 for a summary of the cost models.

Purpose-built buses are more economical than either medium-duty minibuses or standard coaches, so the question of when these vehicles should be selected must be asked. The answer lies in the structure of operating costs. At the wage scales selected for this analysis, it costs $19.00 to keep a driver on the road for an hour no matter what type of vehicle he is driving. A purpose-built minibus can save 5.4 cents per kilometer or 99 cents per hour at 18 kilometers per hour (11 mph.) when compared to a standard bus. This indicates that on a vehicle for vehicle substitution, 19 minibuses could save roughly the equivalent operating cost of one driver and standard vehicle.

However, on the capacity side, a purpose-built minibus has about one-half the capacity of a standard bus, so one standard bus could replace two minibuses if the passenger load required it. In low passenger volume situations, it takes 19 minibuses to generate cost savings equivalent to one standard bus and driver, while in a higher volume situation only one standard bus could replace two minibuses and drivers. Unless a transit operation is very unlikely to experience capacity problems, the

extra capacity of standard buses has greater potential for keeping costs down than does the slightly lower operating cost of a purpose-built minibus.

The situation in which purpose-built minibuses can be most economical is when policy, not passenger demand, dictates vehicle frequency. Minibuses can provide needed frequency in this situation without excess vehicle capacity. For example, airport shuttles must run at least every 4 or 5 minutes to avoid excessive passenger delay, but the capacity of a 53 passenger bus is seldom needed. Similarly, in any shuttle-type service where policy constraints set the service interval in excess of what demand would require, minibuses are cost effective. However, in any situation where passenger volumes dictate a service interval equal to or in excess of what policy considerations would deem adequate, a standard coach is most cost effective.

The operating policy leading to the least costly service is to provide the minimum service interval that will both carry the passenger volume and be adequate to attract riders. For traditional urban bus service, this has been found to be a 12-minute minimum frequency.[1/] In specialized applications like shuttle services, the minimum frequency may be much higher.

Figure IV-4 illustrates the annual operating cost of carrying a specified volume of peak period passengers using different vehicle types. The service hypothesized for the case shown in Figure IV-4 is a route 6.6 km (4 miles) in length (one way) with 20 km/hr. (12 mph.) average speed and an average passenger trip length of 3.3 km (2 miles). The

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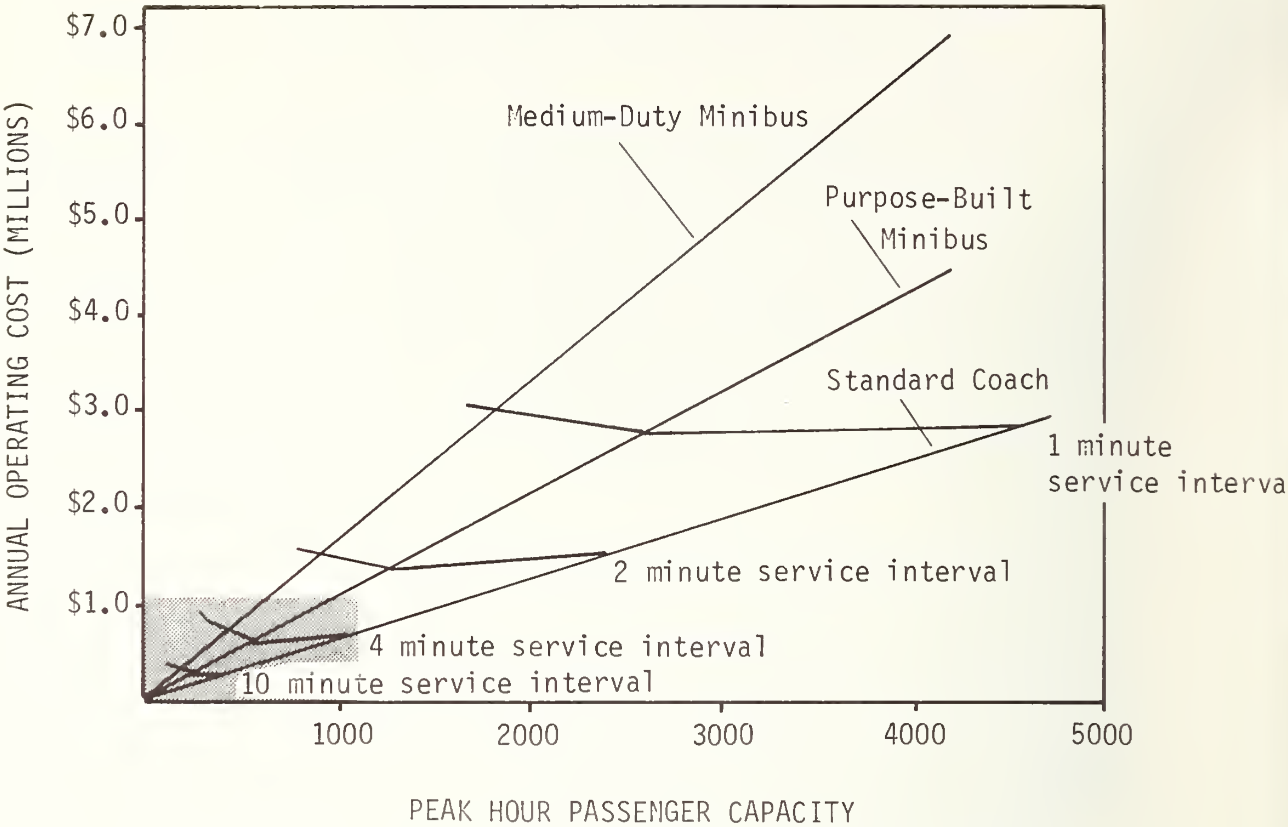
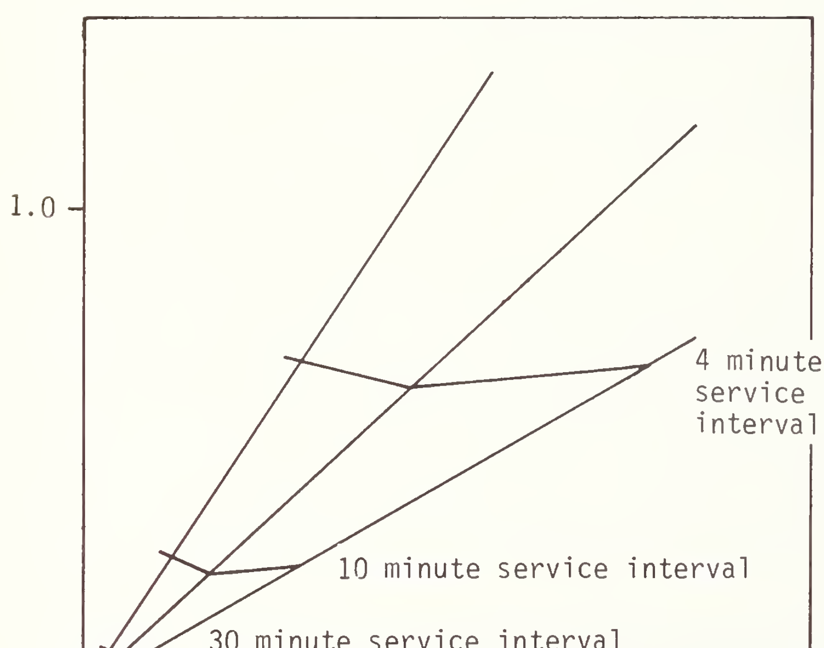
1. Transit Development Program For The City of Fitchburg, Mass., 1977, and USDOT/UMTA, Patronage Impacts of Changes in Transit Fares and Services, 1980.

FIGURE IV-4

COMPARATIVE ANNUAL OPERATING COSTS
AT CONSTANT LOAD FACTOR





Note: Costs assume the following: 4 mile route length; 2 mile average passenger trip length, load factor of 0.4 passenger miles per seat mile; 9.5 equivalent service hours per day; service annualization factor of 310. The horizontal lines indicate constant service intervals across the three vehicle types.

ratio of seat kilometers to passenger kilometers is held constant at 0.4, so the passenger loading is equivalent across the three vehicle types shown.

Applying the cost models developed in this study shows that at a specified service interval, a standard coach can carry a much larger volume of passengers than a minibus at only slightly higher cost. Conversely, a given volume of passengers can be carried at substantially lower cost using a standard coach. The only limit to this rule occurs at very low passenger volumes (less than 100 passengers per hour per route) in which case the service interval afforded by a standard coach may exceed policy guidelines or the limits of passenger acceptance. At this point, the combination of vehicle frequency and passenger demand are sufficiently low that minibuses become most efficient. In other words, service interval policy is the constraining factor, not passenger demand.

This illustration reinforces the conclusion that the most effective role for minibuses is in situations where passengers require higher frequency of service than the passenger demand would warrant. The fuel efficiency advantage of purpose-built minibuses then becomes a factor arguing for the smaller vehicles.

V. CONCLUSION

Table V-1 is a summary of the prototypical cases examined in the previous chapter. The summary emphasizes the "passenger place" concept utilized in other transit technology studies to compare vehicles of different size. Purpose-built minibuses with room for 30 seated passengers and 20 standees are shown for all three cases in Table V-1, and a standard coach with room for 53 seated passengers and 27 standees is also shown for the high capacity system.

Table V-2 compares the costs of providing the same levels of service using each vehicle type. Since the capacity ranges of medium-duty minibuses and purpose-built minibuses overlap, this is an acceptable comparison. However, comparing a vehicle at the low capacity end of the medium-duty range (20 seat vehicle) with a vehicle at the high capacity end of the purpose-built range (31 seat vehicle) would be somewhat misleading. The smaller vehicle would have a higher load factor and, therefore, a poorer level of service than that offered by the larger vehicle. At the generic vehicle level of discussion, however, the comparison is useful.

The conclusion to be drawn from Table V-2 is that the cost characteristics of medium-duty and purpose-built minibuses are indistinguishable when evaluated on a total annualized cost basis. On an operating cost basis only, medium-duty minibuses are about 5% more costly than purpose-built coaches.

If a minibus is the appropriate vehicle to utilize according to the criteria developed in Chapter IV, it makes little difference from a long term economic point-of-view whether purpose-built or medium-duty vehicles are selected. The costs are the same for all intents and purposes.

TABLE V-1

SUMMARY OF PROTOTYPICAL MINIBUS APPLICATIONS

	Feeder	Downtown Shuttle	High Capacity System	
	Purpose-Built Minibus	Purpose-Built Minibus	Purpose-Built Minibus	Standard Coach
Passenger Places/Coach	50	50	50	80
Coaches Required to Meet Schedule	8 Peak, 4 Base	6	9	5
Fleet Required	11	7	20	11
Daily Vehicle Kilometers	2053	800	3300	1867
Daily Vehicle Hours	88	60	180	102
Daily Place Kilometers	102,650	40,000	165,020	149,360
Daily Passengers	2940	3360	16,000	16,000
Daily Passengers/Place Kilometer	0.03	0.08	0.10	0.10
Daily Passengers/Vehicle Kilometer	1.43	4.2	4.85	8.56
Total Annualized Capital,[1/] Operating and Maint. Cost	$933,900	$586,620	$1,859,860	$1,143,430
Total Annualized Cost Per:				
Vehicle Kilometer	$1.54	$2.36	$1.79	$1.97
Vehicle Hour	$36.00	$31.50	$32.88	$36.16
Place Kilometer	$0.03	$0.05	$0.04	$0.02
Passenger	$1.22	$0.56	$0.37	$0.23
Coach	$84,900	$83,800	$91,700	$103,950

1. Total annualized capital cost at 10% discount rate plus annual operating cost.

TABLE V-2

COST SUMMARY OF PROTOTYPICAL
MINIBUS APPLICATIONS

	Feeder		Downtown Shuttle		High Capacity Loop		
	Purpose-Built	Medium-Duty	Purpose-Built	Medium-Duty	Purpose-Built	Medium-Duty	Standard Coach
Annual Operating Cost	$771,900	$819,148	$483,720	$503,060	$1,540,066	$1,619,860	$901,432
Total Annualized Cost	$933,900	$951,148	$586,620	$587,060	$1,834,000	$1,859,860	$1,143,430
Annual Operating Cost Per Vehicle Kilometer	$1.27	$1.35	$1.95	$2.03	$1.51	$1.58	$1.56
Total Annualized Cost Per Vehicle Kilometer	$1.54	$1.57	$2.36	$2.37	$1.79	$1.82	$1.97
Total Annualized Cost Per Passenger	$1.22	$1.24	$0.56	$0.56	$0.37	$0.37	$0.23

From a day-to-day operating point-of-view, however, the purpose-built vehicle is superior because of lower operating costs. This is primarily the result of a lower maintenance cost component. A companion factor which must be considered, but which this report was not able to conclusively assess, is reliability. Transit operators prefer purpose-built vehicles because they are able to keep them in service with fewer breakdowns. Lower maintenance costs reflect this feature. Reliability data were very sketchy, however, so hard evidence is unavailable.

Accepting, for the moment, the operator's perception that reliability of purpose-built vehicles is superior to medium-duty coaches, and that total annualized costs are essentially equal for both vehicle types, the purpose-built coach would be preferred. The fact that purpose-built coaches last three to four times longer than medium-duty coaches is an additional operational benefit, because the maintenance staff does not have to become accustomed to new vehicles as frequently. This study found that even though life cycle costs are essentially equal between medium-duty and purpose-built coaches, transit operators prefer purpose-built because of the day-to-day operating advantages.

LIST OF SOURCES

1. The Applicability of Non-Standard Buses For Service in the Washington Metropolitan Area, Washington Metropolitan Area Transit Authority, September, 1980.

2. SG Associates, Inc., Technical Memorandum No. 1, Dane County Phase I Alternatives Analysis, Bus Operating Costs and Impacts, February, 1980 (Unpublished).

3. Iowa Department of Transportation, Bus Specifications and Price Summary, December, 1976.

4. Bus Route and Schedule Planning Guidelines, NCHRP #69, May, 1980.

5. Interim Materials on Highway Capacity, Transportation Research Circular #212, January, 1980.

6. Transit Development Program for the City of Fitchburg, Mass.

7. USDOT/UMTA, Patronage Impacts of Changes in Transit Fares and Services, 1980.

APPENDIX A

ADJUSTMENTS TO MINIBUS OPERATING COST MODELS

For planning purposes, it is useful to be able to adjust the minibus operating cost models to wage and operating conditions in a particular environment. This section illustrates the mechanism required to adjust the models.

Distance-Related Costs

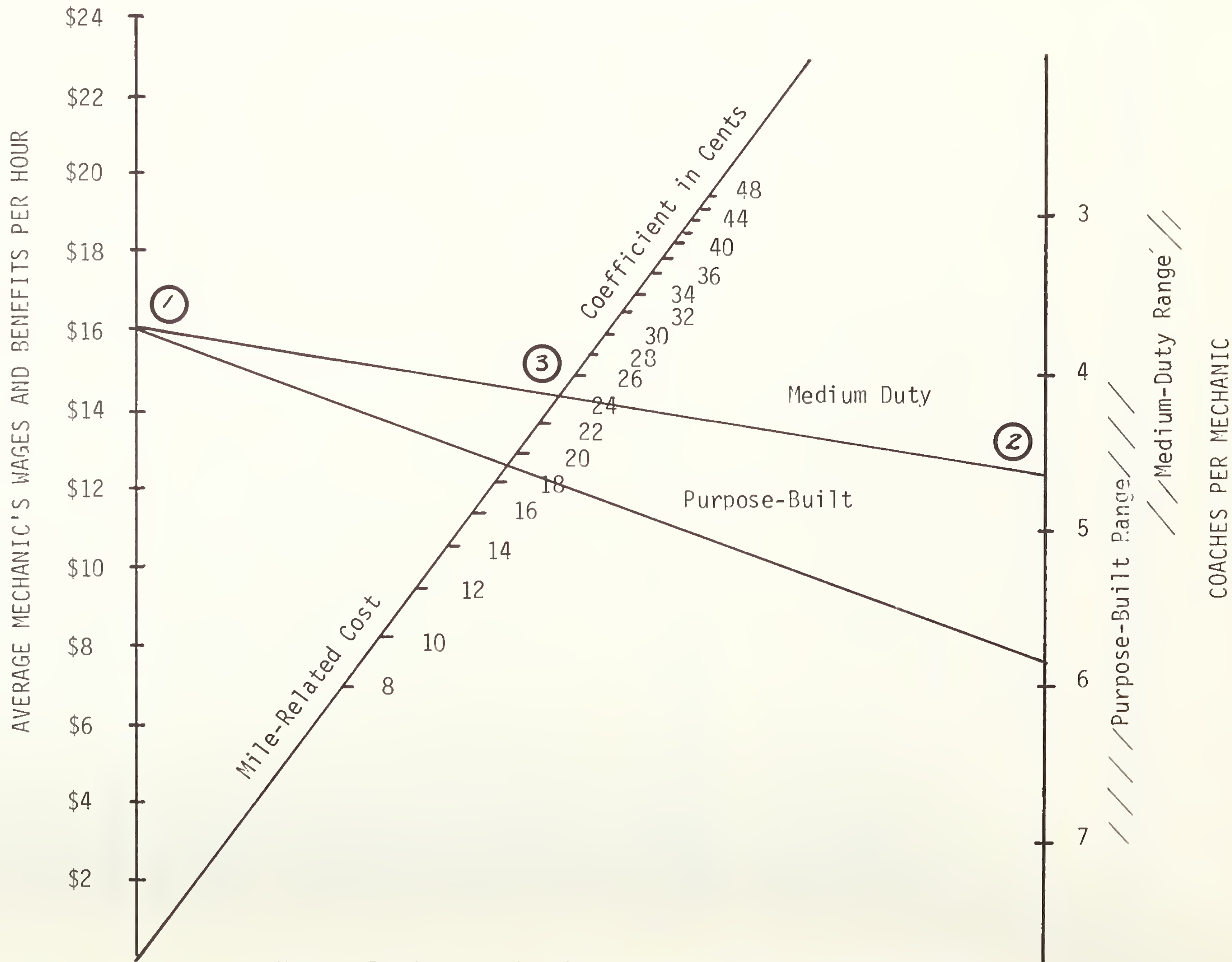
Distance-related costs are composed of fuel expenditure, maintenance labor and maintenance parts and materials. The fuel expenditure component of the default model is based on 2.1 km/l (4.8 mpg) for minibuses and fuel cost of 32 cents per liter ($1.20 per gallon). This yields a per-kilometer cost of $0.15 for fuel ($0.25 per mile). This component c be adjusted simply by updating the fuel price and using a manufacturer's fuel efficiency estimate for the particular vehicle to be utilized.

Maintenance labor and benefits costs are a function of wage rates and maintenance policy. Maintenance policy can be expressed as the ratio of coaches to mechanics. The industry average runs from 4 to 6 coaches per mechanic. Typically, small properties are closer to 6 per mechanic and large properties closer to 4 coaches per mechanic.

Figure A-1 is a nomograph that illustrates cost per mile as a function of wage rate and coaches per mechanic. By drawing a line through the combination of the average wages plus benefits rate and the number of mechanics per coach to be utilized, the maintenance labor cost per revenue vehicle mile can be read off the diagonal line. An assumption underlying this chart

FIGURE A-1

NOMOGRAPH FOR CALCULATING MAINTENANCE LABOR AND BENEFITS COST COEFFICIENT



Note: Read chart in the sequence shown in the example

is that each coach averages 30,000 revenue vehicle miles per year. This is accepted industry practice. This chart can be used for both medium-duty and purpose-built small buses. It should be remembered, however, that medium-duty small buses tend to fail more frequently when used in transit service than do purpose-built coaches, so the maintenance policy for a property that uses these coaches should include a lower ratio of coaches to mechanics.

For parts and materials data show purpose-built coaches requiring 8 cents per kilometer (13 cents per mile) for parts and medium-duty coaches requiring 13 cents per kilometer (21 cents per mile).

To arrive at the vehicle miles coefficient in the cost model, add the per-mile rate for fuel, labor and materials. The default values used in the report are as shown:

	Purpose-Built		Medium-Duty	
	Cost Per Kilometer	Cost Per Mile	Cost Per Kilometer	Cost Per Mile
Fuel	$0.15	$0.25	$0.15	$0.25
Labor and Benefits	0.11	0.19	0.14	0.24
Parts and Materials	0.08	0.13	0.13	0.21
Total Mile-Related Costs	$0.34	$0.57	$0.42	$0.70

These default values can be adjusted as required by the circumstances of a particular application.

Hour-Related Costs

The coefficient for hour-related costs is the average rate for drivers' wages and benefits paid. A default value of $19 per hour was used in the text. Note that revenue vehicle miles is used as the independent variable, so the coefficient must reflect the cost of wages,

benefits and a pay hour factor. Pay hours are typically about 45% greater than revenue hours because of pull-on/pull-off costs, reliefs and spread time payments.

Therefore, Revenue Hours x 1.45 x Average Wage Rate x Benefit Rate is equivalent to the coefficient for vehicle hours. An average wage rate of $10 per hour and a 30% benefit package would yield a coefficient of 18.9. A default value of $19 per revenue vehicle mile is used in the analysis.

If a minibus operation is not to be subject to standard transit industry labor agreements and wage scales, this coefficient can be scaled back according to the anticipated labor arrangements.

Overhead Costs

Overhead costs relate to the size of the transit operation. Administration, utilities, insurance, etc. bear a fairly constant relationship to the number of coaches in a transit fleet. A value of $6500 per coach is used in the text, based on data from several properties operating small buses.

APPENDIX B

DATA FROM TRANSIT PROPERTIES
THAT OPERATE MINIBUSES

TABLE B-1

UNADJUSTED ANNUAL COSTS AS REPORTED

System	Operating Environment	No. of Buses	Av. Fleet Age	Minibus Model	Hours of Operation	Average System Speed	Average Annual Riders
A	Large Airport	16	4+ years	Mercedes 0309D	18 hrs./day	5.9*	1.74 million
B	Small City (population 43,000)	12	1+ years	Chance RT-50	8 hrs./day	11.9 mph.	1500/day 360,000/year*
C	Small City (population 48,767)	10	2 years	Chance RT-50	10 hrs./day	11.9 mph.	540,000
D	Suburb of Large City (population 600,000)	121	--	System Average	19 hrs./day	10 mph.	4,716,458
		19	5 years	Grumman 15 Pass.(Gas)			
		10	4 years	Carpenter 23 Pass.(Gas)			
		19	4 years	Carpenter 27 Pass.(Diesel)			
		19	4 years	Carpenter 35 Pass.(Diesel)			
		7	4 years	Superior 35 Pass.(Diesel)			
		47	1 year	TMC Citycruiser			
E	CBD of Large City (population 3.2 million)	15	3 years	Flxible HD-31 31 Pass.(Diesel)	12 hrs./day	4 mph.	--
F	CBD of Medium-Sized City (population 925,000)	10	--	Transcoach 20 Pass.(Diesel)	9 hrs./day	3 mph.	--
G	Suburb of Large City (population 50,000)	10	2 years	Chance RT-50	8 hrs./day	11 mph.	481,300

TABLE B-1 (Continued)

MINIBUS OPERATING CHARACTERISTICS AS REPORTED

System	Minibus Model	Annual Veh. Miles	Annual Veh. Hours	Personnel: Operating	Personnel: Maint.[1]	Personnel: Admin.	Fleet Fuel Efficiency	Oil/ 10,000 mi.	Miles Between Road Calls	Av. Time To Repair
A	Mercedes 0309D (Diesel)	540,000	92,000	35	(2)	1	5.5 mpg.	--	--	--
B	Chance RT-50 (Diesel)	350,000	29,376	17	5(2)	3	5.9 mpg.	13 quarts	3-10,000 miles	4-6 hours
C	Chance RT-50 (Diesel)	432,592	36,480	13.6	2.5	2.6	5.7 mpg.	23 quarts	7,000 miles	22 hours/ month/bus
D	System Average	1,885,335	186,943	200[2]	--[3]	5	--	--	937 miles	--
	Grumman 15 Pass. (Gas)						5.3 mpg.			
	Carpenter 23 Pass. (Gas)						3.7 mpg.			
	Carpenter 27 Pass. (Diesel)						5.6 mpg.			
	Carpenter 35 Pass. (Diesel)						4.9 mpg.			
	Superior 35 Pass. (Diesel)						5.3 mpg.			
	TMC Citycruiser						3.5 mpg.			
E	Flxible HD-31 31 Pass. (Diesel)	--	--	--	--	--	3.2 mpg.	--	--	--
F	Transcoach 20 Pass. (Diesel)	14,480	29,260	--	--	--	7.1 mpg.	--	--	2.5% Downtime
G	Chance RT-50 (Diesel)	315,364	28,700*	25	3.5	2.5	5.83 mpg.	--	--	--

1. Number in parentheses is the number of mechanics. Number not in parentheses includes washers, cleaners, etc.
2. 140 full-time drivers, 40 part-time drivers, 15 controllers, 5 supervisors.
3. Maintenance employees work on all vehicles operated by the county. Five to six vehicles per mechanic county-wide is typical.

*Indicates estimate by SG Associates from operator data.

TABLE B-1 (Continued)

MINIBUS OPERATING CHARACTERISTICS AS REPORTED

System	Average Wage Rate (1980$)		Benefits Multiplier	Driver Wages And Benefits	Maint. Labor And Benefits	Administration			Average Parts & Material Expense	Fuel Expense
	Drivers	Mechanics				Wages	Ins.	Other		
A	$4.00	$7.00	1.25	$460,000*	$35,000	-----Not Allocated-------			$55,000	$98,000
B	---	---	---	$187,367	$25,657	$37,600	$21,000	$10,000	$51,444	$71,550
C	$5.00	$7.50	---	$165,932	$41,046	--------$42,963-----------			$34,982	$35,328
D	$5.50	$8.00	1.30	(see next page for more detail)					---	---
E	---	---	---	(see next page for more detail)					---	---
F	---	---	---	---	---	--------------------------			---	---
G	---	---	---	---	---	--------------------------			---	---

TABLE B-1 (Continued)

UNADJUSTED ANNUAL COSTS AS REPORTED

COSTS PER VEHICLE MILE (FY 1980)4/

System	Minibus Model	Total Maintenance	Fuel And Oil	Subtotal: Maint., Fuel, Oil & Driver Expense	Admin. Labor	Admin. Non-Labor	Total
D	System Average	57.3¢	---	168.6¢	6.6¢	14.2¢	189.4¢
	Grumman 15 Pass.(Gas)	49.4	20.3¢				
	Carpenter 23 Pass. (Gas)	35.0	26.0				
	Carpenter 27 Pass (Diesel)	37.6	16.8				
	Carpenter 35 Pass. (Diesel)	49.4	20.4				
	Superior 35 Pass. (Diesel)	60.1	22.1				
	TMC Citycruiser	20.8	25.7				

COSTS PER VEHICLE MILE (Without Benefits and Administration)5/

System	Minibus Model	Maintenance Labor	Parts	Fuel & Oil	Tires	Sum (without driver cost)
E	Flxible HD-31	9.7¢	13¢	27.6¢	2.5¢	52.8¢

4. Based on 1 year of operating data -- FY 1980.
5. Based on 15,000 vehicle miles of operation -- 15 vehicles over one month (November 1980).

APPENDIX C

CHARACTERISTICS OF SELECTED MINIBUSES

TMC
Citycruiser T-30

Wheelbase -- 180"

Dimensions
  Exterior
    Length -- 378"
    Width -- 96" (excluding mirrors & opened doors)
    Height -- 114"
  Interior
    Length *
    Width *
    Height *

Passenger Capacity
  Seated -- 31
  Standees -- 30

Space
  Sq. ft. *

Doors
  No. -- 2
  Type -- front -- one piece, rear-folding
  Width *
  Location -- front -- right hand side in front of front wheel
    rear -- right hand side in front of rear wheel

Engine
  Location -- rear
  Type -- Detroit Diesel 6V53T
  No. Cyclinders -- 6
  Rated HP *

Accessories
  Air conditioning -- optional
  E&H Lift -- optional

Transmission *

Minimum Turn Radius -- 33'

Suspension
  Front -- air
  Rear -- air springs

Brakes -- air

Estimated Cost
  Base Vehicle *
  Air conditioning *
  E&H Lift *

Estimated Life *

Wet Weight -- 19,800 lbs.

Gross Weight -- 33,200 lbs.

No. Tires -- front -- single
  rear -- dual

Kneeler -- optional

Fuel Capacity -- 90 gallons

Average Fuel Consumption *

Door Opening Widths
(clear openings)
  Front -- 31"
  Rear -- 31"

* indicates information not available

Source: Transportation Manufacturing Corp., a subsidiary of Greyhound Corp., Roswell, New Mexico.

TMC Citycruiser T-30

CHANCE MANUFACTURING
RT-50

Wheelbase -- 168"

Dimensions
  Exterior
    Length -- 318"
    Width -- 96"
    Height -- 122"
  Interior
    Length -- 288"
    Width -- 90.5"
    Height -- 75"

Passenger Capacity
  Seated -- 25
  Standees -- 15

Space
  Sq. ft. -- 110 sq. ft.

Doors
  No. -- 1
  Type -- bifold
  Width -- *
  Location -- between front & rear wheels, right side

Engine
  Location -- front
  Type -- catepillar Diesel Series 3208-175
  No. Cyclinders -- 8
  Rated HP -- 175

Accessories
  Air Conditioning -- standard
  E&H Lift -- optional

Transmission -- automatic four-speed

Minimum Turn Radius -- 26½'

Suspension
  Front -- full air spring
  Rear -- full air ride type

Brakes -- air

Estimated Cost
  Base Vehicle
  Air Conditioning -- $95,000
  E&H Lift -- $15,000

Estimated Life -- 10-15 years

Wet Weight -- 14,500 lbs.

Gross Weight -- 22,000 lbs.

No. Tires -- front -- single
  rear -- dual

Kneeler -- optional

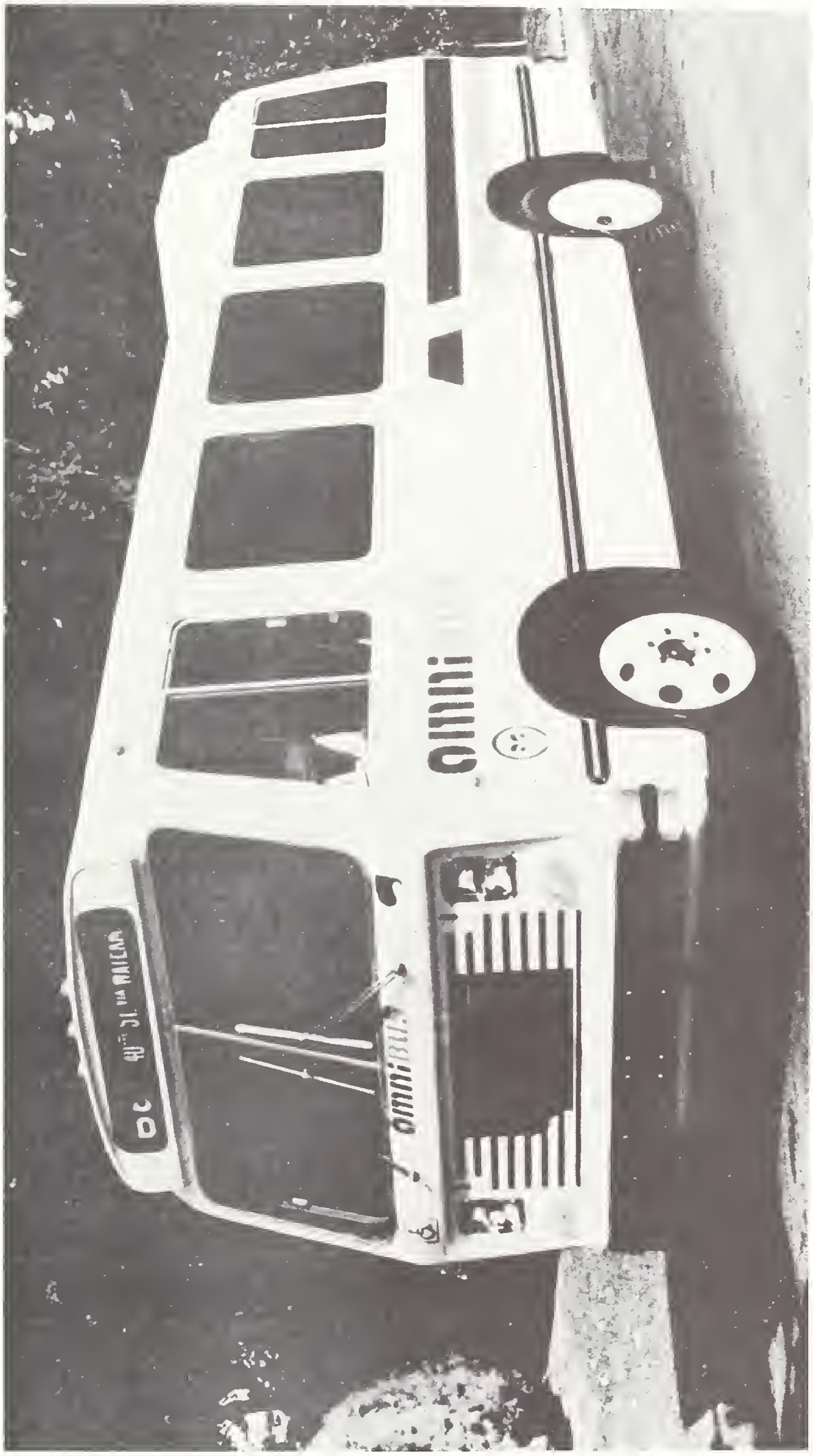
Fuel Capacity -- 50 gallons

Average Fuel Consumption -- 7-8 mpg.

Door Opening Widths
(clear openings)
  Front -- 41"

* indicates information not available

Source: Chance Manufacturing Company, P. O. Box 12328, Wichita, Kansas 67277



CHANCE RT-50

MERCEDES-BENZ O 309 D
(No longer marketed in U.S.)

Wheelbase -- 137.8"

Dimensions
  Exterior
    Length -- 236.2"
    Width -- 83.4 (excluding mirrors & opened doors)
    Height -- 120"
  Interior
    Length -- *
    Width -- 74"
    Height -- 74.8"

Passenger Capacity
  Seated -- 31
  Standees -- 30

Space
  Sq. ft. *

Doors
  No. -- 1
  Type -- front folding
  Width -- 31.8:
  Location -- front -- right hand side behind front wheel

Engine
  Location -- front
  Type -- Mercedes Diesel 230 $in.^3$
  No. Cyclinders -- *
  Rated HP -- *

Accessories
  Air Conditioning -- optional
  E&H Lift -- optional

Transmission -- four speed Allison Automatic at 540

Minimum Turn Radius -- 20'

Suspension
  Front -- leaf spring
  Rear -- leaf spring

Brakes -- air assisted hydraulic

Estimated Cost
  Base Vehicle *
  Air Conditioning *
  E&H Lift *

Estimated Life *

Wet Weight -- 7640 lbs.

Gross Weight -- 10,575 lbs.

No. Tires -- front -- single
  rear -- single

Kneeler -- none

Fuel Capacity -- 21 gallons

Average Fuel Consumption *

Door Opening Widths
(clear openings)
  Front -- 31.8"

* indicates information not available

Source: Mercedes-Benz of North America, One Mercedes Drive, Montvale, New Jersey 07645.

MERCEDES O 309 D

Wheelbase -- 137"

Dimensions
  Exterior
    Length -- 243"
    Width -- 96" (excluding mirrors & opened doors)
    Height -- 112"
  Interior
    Length -- *
    Width -- 88"
    Height -- *

Passenger Capacity
  Seated -- 17-19
  Standees -- 8

Space
  Sq. Ft. -- 148 sq. ft.

Doors
  No. -- 1
  Type -- front folding
  Width -- 30"
  Location -- front -- right hand side behind front wheel

Engine
  Location -- front
  Type -- 350 in.^{3} Gasoline
  No. Cyclinders -- V-8
  Rated HP -- *

Accessories
  Air Conditioning -- optional
  E&H Lift -- optional

Transmission -- Three-speed mechanical

Minimum Turn Radius -- 26'

Suspension
  Front -- spring
  Rear -- spring

Brakes -- hydraulic

Estimated Cost
  Base Vehicle -- $16,000 (1976$)
  Air Conditioning -- $2400 (1976$)
  E&H Lift -- *

Estimated Life *

Wet Weight -- 7900 lbs.

Gross Weight -- 10,600 lbs.

No. Tires -- front -- single
  rear -- single

Kneeler -- none

Fuel Capacity -- 40 gallons

Average Fuel Consumption *

Door Opening Widths (clear openings)
  Front -- 30"

* indicates information not available

Source: Grumman Allied Industries, 600 Old Country Road, Garden City, New York 11530.

GRUMMAN

TRANSCOACH
(Out of Production)

Wheelbase *

Dimensions
  Exterior
    Length -- 280"
    Width -- *
    Height -- *
  Interior
    Length *
    Width *
    Height *

Passenger Capacity
  Seated -- 20
  Standees -- 8

Space
  Sq. ft. *

Doors
  No. -- 1
  Type -- front -- one piece
  Width -- 30"
  Location -- front -- right hand side behind front wheel

Engine
  Location -- front
  Type -- Detroit Diesel 4-53
  No. Cyclinders -- 4
  Rated HP -- *

Accessories
  Air Conditioning -- optional
  E&H Lift -- optional

Transmission -- Allison at 540

Minimum Turn Radius -- 33'

Suspension
  Front -- air
  Rear -- air

Brakes -- air

Estimated Cost
  Base Vehicle *
  Air Conditioning *
  E&H Lift *

Estimated Life *

Wet Weight *

Gross Weight -- 22,000 lbs.

No. Tires -- front -- single
  rear -- dual

Kneeler -- none

Fuel Capacity *

Average Fuel Consumption *

Door Opening Widths
(clear openings)
  Front -- 30"

*indicates information not available

Source: Sportscoach Corporation, 9601 Canoga Avenue, Chatsworth, California 91311

TRANSCOACH

APPENDIX D

REPORT OF NEW TECHNOLOGY

This report represents the first time field operating data has been assembled on minibus performance and organized to assist planners with vehicle selection decisions. It normalizes operating cost and performance characteristics from a number of different transit properties to derive generic operating costs and performance characteristics of minibuses in selected operating environments. The report concentrates on the new generation of 30- to 31-foot minibuses which are fast finding favor with many small bus operators. It illustrates operating costs likely to be incurred in a medium to large city environment, but also provides a mechanism to adjust cost estimates according to particular policy and wage conditions.

This report was originally conceived as part of UMTA's Downtown People Mover research. This research effort included information gathering on many transit modes for use in DPM analysis. Minibus technology was one such mode. It is part of UMTA's ongoing effort to document the characteristics of many urban transportation modes.

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